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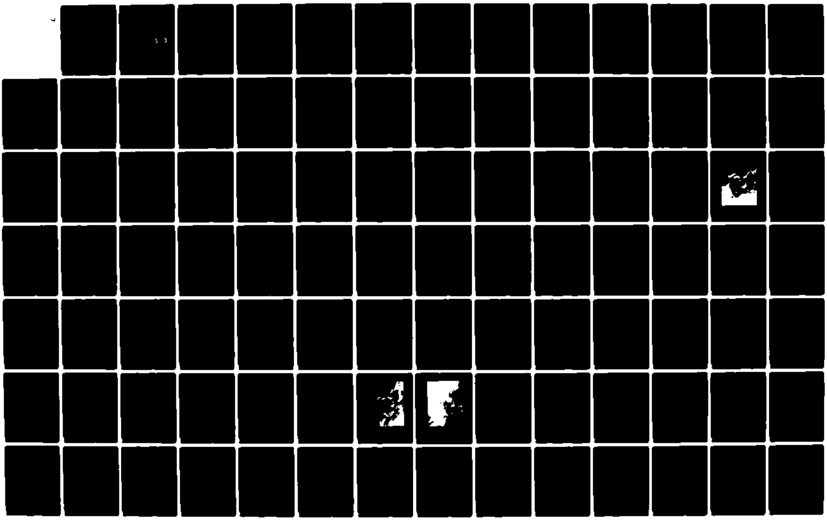

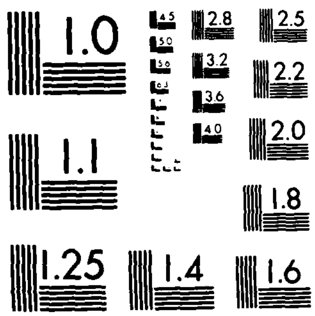

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A STATISTICAL-DYNAMICAL MODEL FOR
FORECASTING COLD AIR STRATOCUMULUS OVER
THE YELLOW SEA

Harold Lloyd Massie, Jr.

ABSTRACT

A statistical-dynamical model is presented for forecasting the areal amount of cold air stratocumulus within a gridded area over the Yellow Sea. For short-range applications, the model is found to offer significant improvement over methods based on persistence and climatology. For forecasts of 12 hours, the model accuracy is 68% for a 0-class error and the skill score is 32% with respect to persistence.

Satellite pictures from NOAA-6 are used in satiscally analyzing cloud amounts from November 1981 through February 1982. Cloud amount (N), defined as the amount of stratocumulus cloud field within the gridded area, is related to stability and relative humidity in the boundary layer. Stability is given by the "boundary layer stability parameter," a quantity based on 850 mb height and temperature and the sea surface temperature. The statistical analysis yields regression equations which are used in a stepwise fashion to predict N. These are combined with a Lagrangian model to complete the statistical-dynamical model.

The Lagrangian model simulates the modification of continental polar air to maritime polar air. Predictors

for the empirical equations are obtained from the numerical simulation. Key variables, such as the 850 mb temperature and relative humidity, were found to agree well with observations. The sensitivity of the simulation to simplifying assumptions is investigated. The model is sensitive to variations in the range of vertical velocity and entrainment rate.

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A STATISTICAL-DYNAMICAL MODEL FOR FORECASTING COLD AIR STRATOCUMULUS OVER THE YELLOW SEA

Harold Lloyd Massie, Jr.
Madison Heights, Virginia

B.S., Lynchburg College, 1973

A Thesis Presented to the Graduate
Faculty of the University of Virginia
in Candidacy for the Degree of
Master of Science

Department of Environmental Sciences

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and Approved by:

Michael Garstang
Major Advisor

Steve Colucci

Bruce P. Hayden

Mahlon Kelly

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TABLE OF CONTENTS

Table of Contents (cont.)

Table of Contents (cont.)

LIST OF FIGURES

List of Figures (cont.)

List of Figures (cont.)

List of Figures (cont.)

LIST OF TABLES

List of Tables (cont.)

List of Tables (cont.)

CHAPTER 1

INTRODUCTION

Cold air stratocumulus is a name often used for the mesoscale convective clouds covering large areas of the western Atlantic and Pacific during winter. These clouds are the products of air-sea interaction as the atmospheric boundary layer is heated and moistened by the ocean. Clouds of this type occur frequently over the Yellow Sea and along the west coast of South Korea during the northwest winter monsoon. Often accompanied by locally heavy snow with low ceilings and restricted visibilities, these clouds create hazardous conditions for all aviation. Thus, their effect on U.S. Air Force facilities and operations in Korea is of particular concern to the Air Weather Service (AWS).

There are few references on operational techniques for defining areas of marine stratocumulus development. The 30th Weather Squadron (30WS) Local Analysis and Forecast Procedures (LAFP) (U.S. Air Force, 1982) discuss this problem from the traditional viewpoints of continuity, persistence, and rules of thumb. Continuity and persistence involve the use of pictures from meteorological satellites to follow the movement of and changes in the stratocumulus cloud field. However, this approach is not applicable unless clouds are already present, leaving unsolved the forecast problems associated with the onset of cloud activ-

ity. Rules of thumb, based on case studies, mostly rely on forecasts of air-sea temperature differences to aid forecasts of developing stratocumulus. Either the surface or the 850-mb temperature is chosen for this purpose. The main weakness of these rules of thumb is the lack of a way to quantify the effects of diabatic processes on the temperature of air flowing over the sea. In most cases the forecaster can only guess how much warming will occur. Temperature changes associated with diabatic heating often cause significant errors in forecasts based on rules of thumb.

Numerical forecast products from the AWS primitive equation model (PE) are readily available to units in Korea. PE forecasts of the 1000-to-500 mb thickness field often help in tracking the movement of cold air masses, but problems arise when one attempts to apply this information to timing the onset or extent of stratocumulus. Because no statistical relationships have been developed between cold air stratocumulus activity and the PE output, the forecaster cannot be certain of the thickness value associated with cloud development. Other products, derived either totally or in part from the PE, furnish area forecasts of low clouds over the Yellow Sea. However, these products often perform poorly for stratocumulus because of the PE's rather broad handling of diabatic processes. Therefore, one concludes there is a need for an effective method of determining areas of marine stratocumulus develop-

ment during cold air outbreaks.

A primary goal of meteorological satellite research has been to obtain quantitative information about conventional atmospheric parameters by using satellite cloud imagery. For example, Rogers (1965) presented a technique for estimating low-level wind velocity from satellite photographs of cellular convection. More recently, Chou and Atlas (1981) developed a means of estimating ocean-air heat fluxes in cold air outbreaks by measuring the displacement of stratocumulus cloud lines. Other studies, many cited by Anderson et al. (1969), have shown correlations between certain recurring cloud patterns and recurring atmospheric conditions. Included among these is the preferred occurrence of cold-air stratocumulus cloud lines to the east of the continents in cold, dry air advancing ahead of an intense anticyclone. Krueger and Fritz (1961) suggested that such activity is promoted by air-sea interaction. The ocean, acting as a source of heat and moisture, rapidly modifies the invading cold air and causes the planetary boundary layer to become convectively unstable.

Both the horizontal and vertical extent of the stratocumulus cloud field depend upon the vertical structure of the boundary layer. Certain similarities with laboratory experiments on cellular convection in a fluid heated from below supply guidance in the selection of parameters for statistical studies of the atmospheric version of this phenomenon. If correlations exist between these parameters

and cloud coverage, as seen in a defined area on satellite pictures, then one can develop empirical equations for stratocumulus activity.

Application of the statistical relationships requires a means of forecasting the needed atmospheric parameters. This problem is not trivial. Again, the main problem is diabatic heating. Air modification over the Yellow Sea leads to forecast errors if parameters are based on simple extrapolation of variables from local weather charts or if they are extracted from the PE.

This thesis will present another approach to the problem of forecasting the required parameters. Predictors will be generated by a simple two-layer Lagrangian model that uses tendency equations to numerically simulate the effects of diabatic processes on temperature and humidity in the boundary layer. This method is inspired by the considerable effort devoted by other researchers to increasing the knowledge of processes involved in oceanic boundary layer modification. Since the chief aim of this research is not a theoretical investigation of the boundary layer but rather to apply the existing theory to the development of a practical forecast tool, the model presented here simplifies the more complex Lagrangian models from which it borrows.

The statistical-dynamical methods of weather forecasting are objective techniques which apply statistical relationships between a predictand and one or more predictors. Panofsky and Brier (1968) have classified these methods:

1. Linear regression or multiple discriminant analysis.
2. Successive graphical regression.
3. Stratification.
4. Residual method.
5. Mixed methods.

The residual method is used in this study.

From the turbulent-radiative theory of organized cellular convection (Oliver et al., 1978) a stability parameter based on the sea surface-to-850 mb temperature lapse rate is chosen as a predictor. The correlation between cloud amount in a defined study area and the stability parameter is investigated by linear regression analysis. Model output is used in analyzing the residuals. The correlation between the residuals and the model output 850 mb relative humidity is likewise determined by linear regression.

In this study cloud amount always refers to the number of 1° latitude by 1° longitude grid cells at least half filled by part of a stratocumulus cloud field located within an area extending from 34 to 37°N and from 123 to 126°E (Figure 1). Both theory and observation show that the spacing between cloud lines is small compared to their width and length. Thus, the spacing between lines is disregarded in counting cloud amount.

The purpose of this thesis is to develop a simple statistical-dynamical model for short-range forecasting of cold air stratocumulus over the Yellow Sea and to test their model by using satellite imagery. The model testing

covers forecast periods of 12, 18, and 24 hours. The skill of the model is evaluated with respect to chance, climatology, and persistence. Another objective of this research is to present the statistical climatology of cold-air stratocumulus during the period of November 1981 through February 1982. The results of the statistical analyses leading to the development of the empirical forecast equations are included. This study suggests that the forecast model has value as an applied forecast tool and that it is suitable for use on a microcomputer in small weather units.

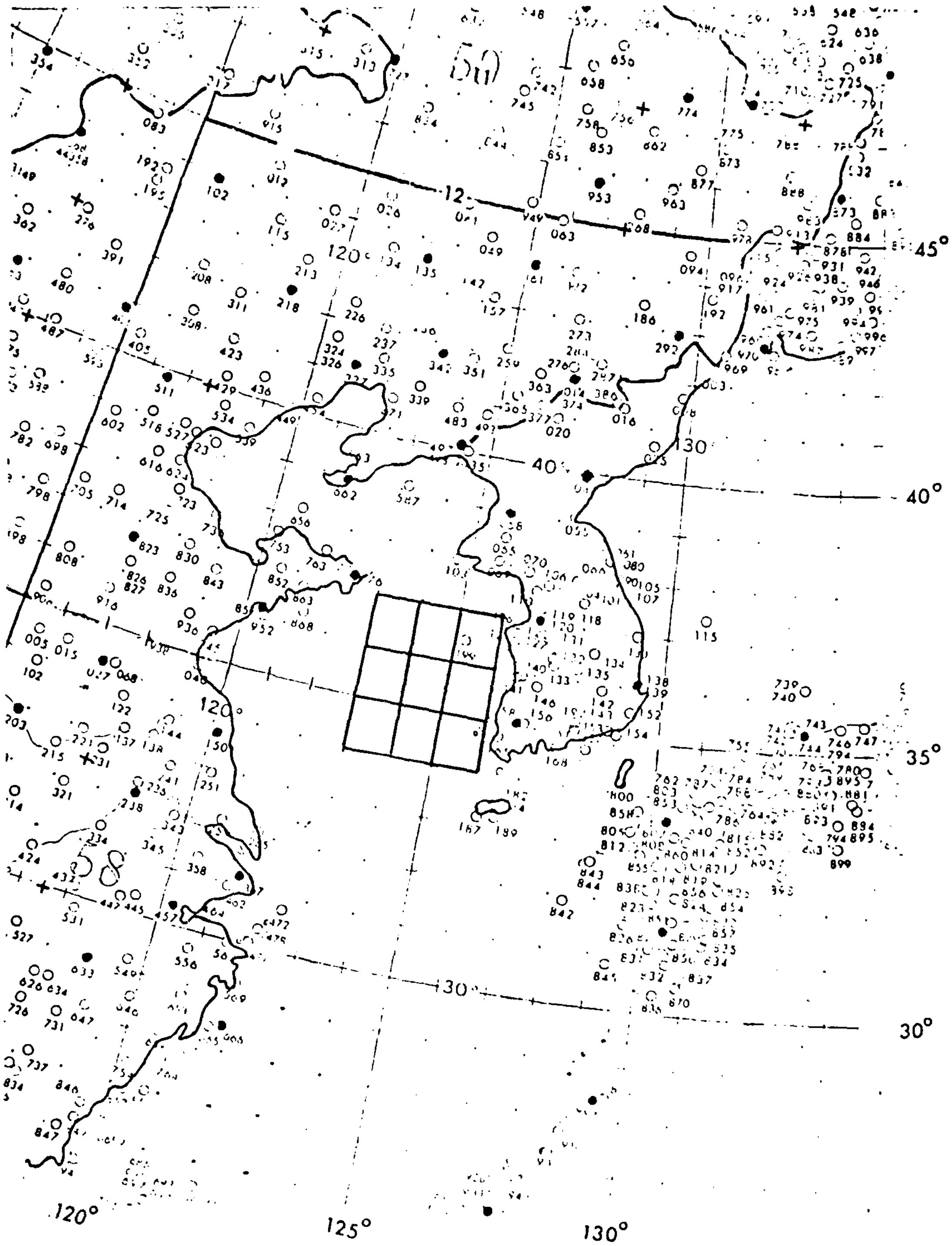

Figure 1. Gridded area used in analyzing the areal amount of cold air stratocumulus.

CHAPTER 2

BACKGROUND

A. THEORY ON CELLULAR CONVECTION

Since the beginning of the meteorological satellite program in 1961, satellite pictures have revealed that vast regions of organized cellular convection occur over the oceans. Although the existence of this phenomenon in the atmosphere is a relatively new observation, the systematic study of cellular convection in gaseous and liquid media began early in this century.

Bénard's classical experiment in 1901 stimulated subsequent research leading to recent progress in the understanding of atmospheric cellular convection (Agee _et al._, 1973). Working with a very thin layer of liquid heated uniformly from below, Bénard induced instability in the fluid. The initially motionless fluid layer then resolved itself into convective cells, each exhibiting rising motion at its center and sinking motion at its common boundary with adjacent cells. Bénard observed two phases of convection. One was described as a short-lived "semi-regular regime" whereas the other consisted of a permanent regime of regular hexagons.

Brunt (1951) describes a simple experiment for simulating cellular convection. A thin layer of gold paint is

poured into a shallow layer in a container. The evaporational cooling at the surface of the volatile liquid produces instability, causing the suspended gold-colored flakes to organize into cellular patterns. Each cell has relatively clear and opaque areas corresponding to a rising core and a sinking boundary, respectively.

The term "Bénard cell," the type of convection observed in Brunt's paint experiment, has caused some confusion in the meteorological literature. The misinterpretation is largely because Bénard's experiments, as well as Brunt's, deal with a different phenomenon in a different medium (Agee et al., 1973). Bénard cells occur in shallow liquids and are driven by surface tension gradients on the free surface. Cellular convection in the atmosphere is driven by buoyancy.

The theoretical study of buoyancy-driven convective cells began with Rayleigh (1916), who determined the criterion for their existence. This criterion states that cellular convection occurs when the density at the top of the fluid layer exceeds that at the bottom by an amount that varies directly as the molecular heat conductivity and viscosity, and inversely as the cube of the depth of the fluid.

Agee et al. (1973) recommended proper nomenclature for the two distinctly different physical processes responsible for natural cellular convection. "Bénard cells" should indicate surface tension-driven cells in liquids with ascending motion but a depressed free surface at the cell center.

"Rayleigh cells" should indicate all buoyancy-driven convective cells. Rayleigh cells may have downward or upward motion at cell center. In Rayleigh cells the fluid surface is elevated above the rising motion and depressed above sinking motion. Figure 2 has been adapted from Agee et al. (1973) and Moyer (1976) to illustrate the two types of cells.

Other research (Graham, 1933; Chandra, 1938; Avsec, 1939) was prompted by the work of Bénard and of Rayleigh. Bénard had suggested that certain cloud patterns in the atmosphere might be similar to the cellular patterns observed in unstable liquids. Thus, it is not surprising that efforts were made to link experimental observations to the atmosphere. In their experiments, researchers induced thermoconvective cellular patterns in smoke-laden air confined within a suitable container. The air inside was destabilized by heating from below.

The Rayleigh criterion predicted the onset of convective behavior if the vertical gradients in temperature and density reached the critical threshold. It was shown that the fluid mixture broke into a series of polygonal cells if no shearing motion in the vertical was present. By introducing shearing motions into the chamber, researchers artificially produced longitudinal rolls in the flowing medium. These rolls exhibited helical motion. The equations governing this flow are very complex and embrace the combined effects of viscosity, buoyancy, and vorticity on the fluid. Extensive discussions of the classical laboratory experiments and the theoretical investigations of Rayleigh

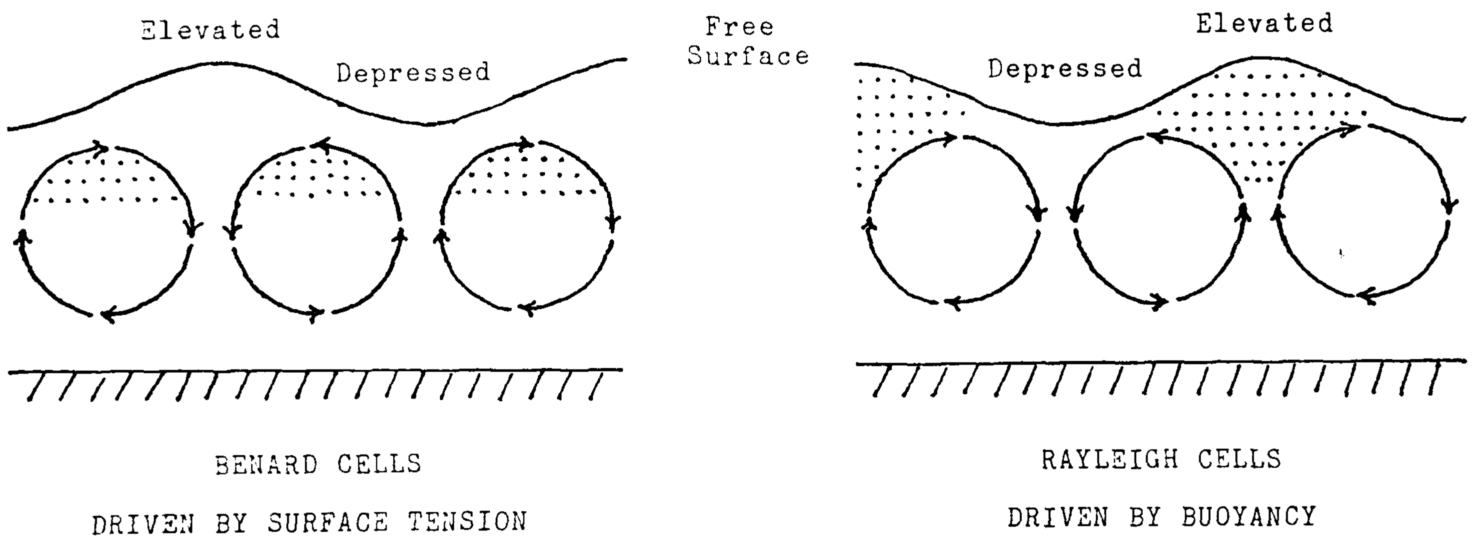

Figure 2. Illustration of the nature of free surface deformations for surface tension-driven Benard cells and buoyancy-driven Rayleigh cells (adapted from Moyer, 1976; Agee <u>et al</u>., 1973).

on fluid instability may be found elsewhere, e.g., Agee et al., 1973; Graham, 1933; Chandra, 1938; Avsec, 1939.

B. ATMOSPHERIC CELLULAR CONVECTION

Meteorological satellites have added a new dimension to the study of organized convective cloud patterns in the atmosphere. These platforms allow meteorologists to study cloud organization and behavior not previously observable from the ground. The basis for systematic study of atmospheric cellular convection is readily suggested by certain similarities of the cloud patterns to those obtained in the laboratory experiments.

In one of the first reports on satellite observations of cellular cloud patterns, Krueger and Fritz (1961) noted that significant differences exist between atmospheric cellular convection and that produced in experimental chambers, despite their strikingly similar appearance. These differences involve scale, structure, heat conduction, viscosity, latent heating, and the spatial variation of heating. The first two can be used for illustration. In the experimental chambers, the diameter-to-depth ratio of the convective cells is on the order of 3-to-1. In the atmosphere, values of up to 10 times this amount are seen. Cells observed in the laboratory show a very simple scale and structure. The walls of the cells observed in the atmosphere actually consist of individual cloud elements, their presence indicating several interacting scales of motion. Nevertheless, the classical theory has provided

important guidance toward a more complete understanding of organized atmospheric convection.

Observation and study of the banded structure of atmospheric cellular convection have been enhanced by meteorological satellites. There is some confusion in the literature over the terminology for these bands. Many writers use the terms "cloud band", "cloud line", and "cloud street" interchangeably. This thesis will follow the AWS definitions (Anderson et al., 1969). According to these, a cloud band is a continuous cloud pattern having a width of at least 60 nautical miles and a length-to-width ratio of at least 4-to-1; a cloud line is a continuous cloud pattern, less than 60 nautical miles in width, and comprised of cloud elements which appear connected on the satellite picture; and a cloud street is a cloud pattern of less than 60 nautical miles in width comprised of cloud elements which do not appear to be connected on the satellite picture.

Kuettner (1959) mentions that glider pilots have supplied much information on cloud street structure. They have observed that a combination of thermal convection and strong winds occur in cloud streets. The pilots take advantage of the tedious circling technique in the columnar thermals for a comfortable tailwind flight. Sea gulls have also enjoyed this method of travel for millions of years.

The cumulus tops of the cloud streets have a definite ceiling, indicating the existence of a temperature inversion

that restricts the vertical motion to a well defined layer. Mountains tend to disturb rather than create cloud streets, hence providing a possible reason why they are best developed over the oceans. The vertical motion consists of updrafts under the cloud base and of downdrafts in the space between bands. The accompanying horizontal winds show strong curvature of wind speed profile in the vertical and contain a maximum within the convective layer. There is very little indication of uniform speed. The variations of wind direction with height are quite small. In most cases the wind speed in the lower part of the layer is considerably higher than normal and at times a jet-like wind maximum appears near the ground. The stable layer is typically located at about 2 km above the ground (Kuettner, 1959).

Kuettner also describes the synoptic situation associated with the development of oceanic extratropical cloud streets. In most cases they occur during outbreaks of polar air advancing over warm water. An intense, cold anticyclone is usually found on the surface analysis in the area affected. The low level wind trajectories extend from the cold air toward the warm water.

The presence of a temperature gradient along the wind flow calls for a decreasing pressure gradient with height. By the time the 700 mb level is reached, not much evidence of a surface high is found. If it were not for friction, the observed winds would have a maximum speed at the surface. Cold air advection, indicated by the temperature gradient

along the flow, requires the winds to back with increasing height. However, the small variation of wind direction with height causes the upper geostrophic wind vector to line up with that of the wind in the lower frictional flow. The curved wind speed profile exists because of the decrease in friction with height in the lower part of the layer and the decrease in thermal wind speed near the top of the layer.

Krueger and Fritz (1961) studied the vertical structure of the boundary layer in regions of cellular convection. They concluded that the lapse rate becomes nearly dry adiabatic in a layer of moist air being heated at the ocean surface. Over this layer lies another of greater stability, serving to inhibit convection. Throughout the convective layer, there are only small variations in wind speed and direction above the part influenced by surface friction. The buoyancy of the cumuliform clouds arises partly from the heating of the air at the surface. It was noted that radiative cooling at the cloud tops also contributes to destabilization of the boundary layer.

Faller (1965) investigated the conditions leading to the development of longitudinal convective rolls. He showed that convection in the turbulent Ekman layer would take the form of stationary roll vortices caused by shear instability in the vertical wind profile. These could then generate clouds if the relative humidity were high enough. The longitudinal axis of these rolls would have a horizontal orientation between the direction of the surface wind and that of the upper geostrophic flow. LeMone (1973) showed

that buoyancy, in addition to vertical wind shear instability, was needed in order to maintain longitudinal rolls.

C. AIR MASS MODIFICATION

Air masses are vast bodies of horizontally uniform air. They may be modified either by thermodynamic or mechanical processes. Thermodynamic modification involves the transfer of heat and moisture between the bottom of the air mass and the surface over which it moves. The extent of modification depends upon the original characteristics of the air, the characteristics of the underlying surface, the air trajectory, and the length of time the air is subjected to change (Trewartha, 1968).

In winter, the general direction of airflow over the Yellow Sea is dominated by the northwest winter monsoon, prevailing over all eastern Asia. During this period, the surface winds appear to originate in a cold anticyclone centered in the Lake Baikal area of Siberia. At its source over the continent, the northwest monsoon is extremely cold, dry, and stable. The seaward advance of this air is not always steady but is in the form of nonperiodic surges. This behavior suggests that the anticyclone is fed at higher levels by expulsions of artic air moving southward on the rear of deep upper tropospheric troughs (Trewartha, 1968).

The magnitude of the Asiatic winter monsoon is a consequence of Asia's size and topography. Because the monsoon remains so fully developed throughout the winter,

the western Pacific probably has the earth's highest frequency of cold air outbreaks and of episodes involving the modification of continental polar (cP) air to maritime polar (mP) air.

As cold, dry air streams off the continent, it immediately undergoes modification due to air-sea interaction. The exchange process causes heat and moisture to be transferred from the sea to the air at the air-sea interface. The well known result of this activity is the development of cold air stratocumulus in the convectively unstable boundary layer.

Figure 3 is a satellite picture from NOAA-7 on 1 December 1981. It shows organized cellular convection in the form of lines of cold air stratocumulus over the Yellow Sea and East China Sea. The downstream changes in cloud pattern from longitudinal convective rolls into polygonal cells are caused by air mass modification and changes in the vertical wind structure. This behavior has been discussed by Hubert (1966).

Many studies have been published on the modification of cP air over warm bodies of water, e.g., Lettau (1944), Craddock (1951), Manabe (1957, 1958), Ninomiya (1972), Lenschow (1973), and Henry and Thompson (1976). Most of these have focused on surface heat fluxes.

Burke (1945) investigated transformation of cP air to mP air by using a semi-empirical method. He divided the boundary layer into three parts (Figure 4). The bottom layer

Figure 3. Infrared satellite picture from NOAA-7 [illegible] December 1981 at 1057 GMT (ascending node at 130.4 [illegible]). The organized cellular [illegible] is [illegible] cloud lines [illegible] and changes to [illegible] cell structure [illegible] cells [illegible] downstream.

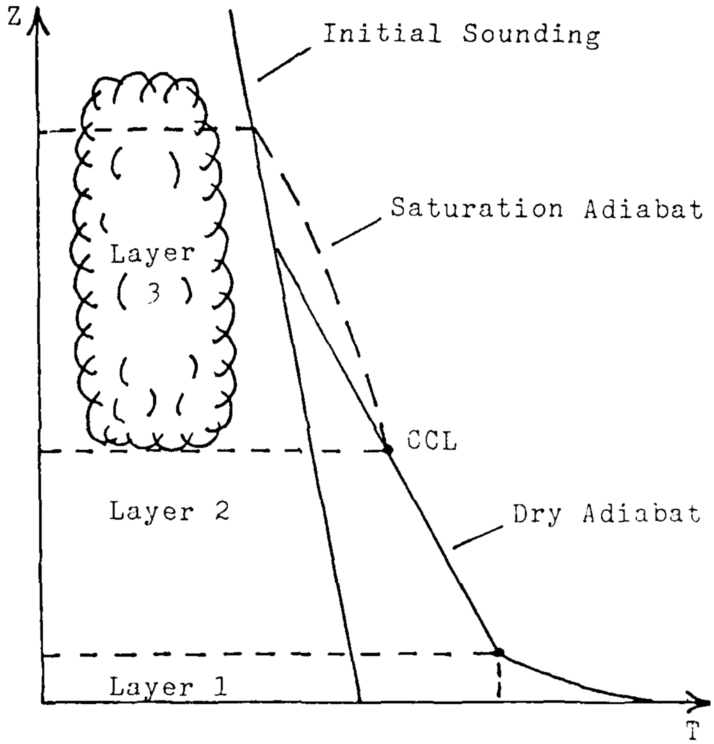

Figure 4. Transformation of cP air to mP air. (After Burke, 1945; Haltiner and Martin, 1957).

extended from the surface to 15 meters and had the steepest moisture and temperature gradients. The second layer was between 15 meters and the cloud condensation level (CCL). It had nearly constant values of potential temperature and specific humidity. The third layer began at the cloud condensation level and extended upward into the cloud layer. It had nearly constant values of equivalent potential temperature. Burke's figure represents the vertical structure of the boundary layer during episodes of cold air stratocumulus if a capping inversion or stable layer is added above the boundary layer (Figure 5).

D. BOUNDARY LAYER MODELS

Lagrangian models have been developed to simulate the behavior of the cloud-topped planetary boundary layer Lilly (1968), Deardorff (1976), Schubert et al. (1979), Stage (1979), Albrecht et al. (1979), Randall (1980), and Stage and Businger (1981). These models simulate changes in the layer with time in air flowing over the ocean. They have greatly improved understanding of the dominant processes in air mass modification. These models use the bulk aerodynamic method to specify surface heat fluxes. They mainly differ in their treatment of radiative fluxes and entrainment. For simplicity, they all assume a characteristic vertical structure for the boundary layer.

Stage (1979) developed a model especially for cold air outbreaks over water. He assumed that the initial characteristics depended upon the past history of the air

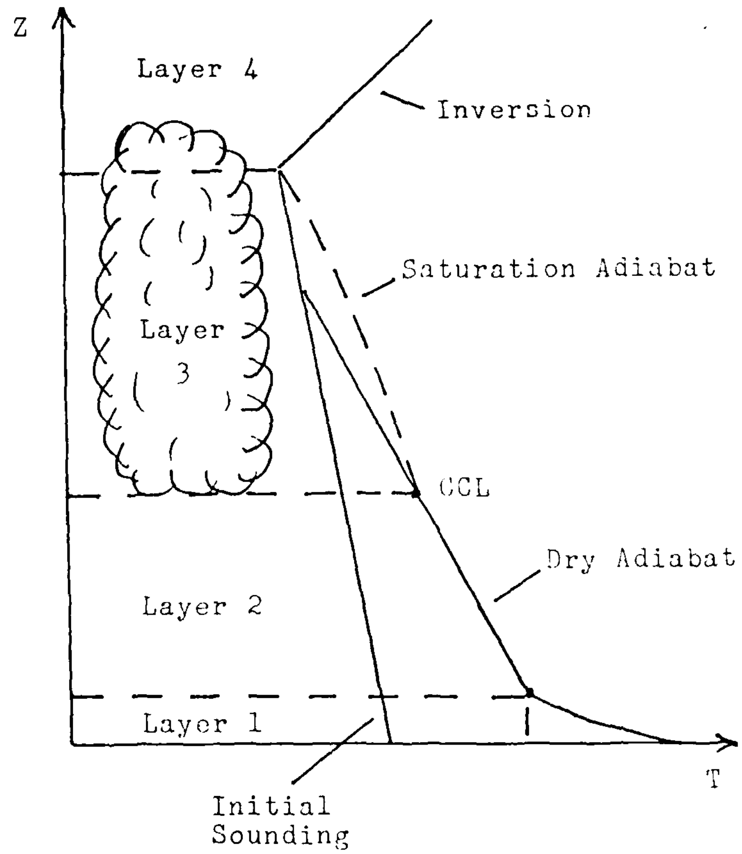

Figure 5. Modification of Burke's figure to show temperature inversion capping the planetary boundary layer.

and the synoptic weather pattern. Since the air is initially much colder than the water, an extremely unstable layer forms near the surface and grows rapidly in height as the air moves farther offshore. After a few kilometers, this layer becomes the PBL and is well mixed from the surface to the capping inversion. As this layer warms and moistens its depth grows slowly by turbulent entrainment of air from the inversion layer. Eventually the air is moist enough for clouds to develop near the top of the layer. Once clouds form, latent heating and radiative cooling of the cloud layer influence the boundary layer energetics. Stage chose to neglect solar radiation in his model. Other important features of Stage's model include:

1. Radiative heat loss near the cloud top occurs entirely within the mixed layer.

2. Turbulent kinetic energy produced by buoyancy is the driving mechanism for entrainment.

E. SATELLITE STUDIES OF MESOSCALE CELLULAR CONVECTION

From the earliest days of meteorological satellites, it was clear that these platforms would greatly enhance studies on cloud behavior. Regions from which observations were not previously available are now monitored by satellites. The result has been an ever-increasing awareness of organized cloud patterns not observable from the ground. Satellite pictures have improved the geographic coverage of cloud data, yielding what one might call a climatology or mesoscale cellular convection (Agee et al., 1973). The recognition that cold air stratocumulus preferably forms east of the continents in outbreaks of cold air is one example.

Analysis of satellite pictures provides three basic types of information about clouds: amount, type, and pattern. It is sometimes possible to determine specific modes of atmospheric behavior such as Rayleigh convection and longitudinal roll vortices.

Satellite pictures have shown that counter-rotating longitudinal rolls are the preferred convective mode for cold air stratocumulus in some regions including the Yellow Sea. The pictures provide evidence of air rising along the axis of each roll and sinking in the clear area between rolls. In most cases, the upwind edge of the cloud field roughly reflects the shape of the coastline where the cold air originates. Except for upwind variations, rolls are often similar in length and width.

When combined with other data, satellite pictures offer new possibilities in the study of cold air stratocumulus. For example, statistical studies can show the frequency of occurrence with respect to certain atmospheric parameters, or probability studies can aid predictions of stratocumulus activity. Holroyd (1971) analyzed the threshold of air-sea temperature difference needed for the onset of cold air stratocumulus over the Great Lakes. He found that clouds form when the 850 mb temperature is more than 13°C colder than the lake surface temperature.

F. STATISTICAL-DYNAMICAL FORECAST METHODS

Objective forecasts of local weather elements can be obtained empirically by applying statistical methods to the

output of numerical prediction models. This approach infers the future behavior of the atmosphere from the statistics of past behavior. In practice, some meteorological element, e.g., cloud amount, temperature, or precipitation, is forecast from past relationships with certain meteorological parameters (Glahn and Lowry, 1972).

The great success of numerical weather prediction during the past two decades has changed weather forecasting. Yet, forecasts based only on numerical models have handled the most important elements, e.g., temperature, precipitation, visibility, ceiling, and cloud amount, with limited success. In fact, most numerical models are not even capable of predicting these elements directly. For this reason, statistical methods have been used to convert the raw output from numerical models into forecasts of certain weather elements.

There are two methods of combining statistical methods with numerical weather models. The first is the perfect prognosis method. Using historical data, this method correlates some local weather element with one or more nearly concurrent atmospheric parameters. Equations derived from these analyses are then applied to the output of numerical prognostic models to produce a forecast of the desired weather element. Errors in the numerical forecast will cause corresponding errors in the statistical forecast. The statistical forecast improves as the numerical forecast improves. One advantage of this method is that stable fore-

cast relations can be derived for individual locations and seasons having a long record of data. A weakness is that errors in the numerical model are disregarded.

The second method is Model Output Statistics (MOS). Like the perfect prog method, it derives its statistical relations on a concurrent basis. However, the developmental sample is based on prognostic data produced by the numerical model, rather than on a long period of observed data. This approach therefore allows for inaccuracies in the numerical model based on past performance. Another advantage is that MOS includes many predictors not readily available to the perfect prog method (Klein, 1974).

A variety of statistical techniques can be used in deriving the empirical forecast equation. Panofsky and Brier (1968) have classified these methods. The residual method used in this research consists of correlating errors of forecasts based on one variable with another variable. Thus, the second variable is used to correct a forecast based on the first. Additional variables can be added so that a third variable is used to correct a forecast based on the first two, etc.

Most statistical forecast methods use fixed-point techniques in which predictors are chosen at the same places for every forecast. These points may either be observing stations or grid points at which the variables are known. For some problems, however, trajectory methods are physically more satisfactory. In this method one must first

determine the initial location of the air that will be at the terminal point at the valid time of the forecast. The difference between the predictand at the beginning and at the end of the trajectory can be linked to other variables expected to modify the air. A disadvantage of this method is that the trajectory can seldom be determined without error. However, fairly accurate short-range trajectories can be constructed based on continuity and persistence of major flow features.

G. FORECAST VERIFICATION METHODS

Forecast verification is usually considered to mean the process of comparing the predicted weather with the weather that actually occurred (Panofsky and Brier, 1968). The data obtained from such comparisons is then used to determine the so-called forecast "skill" against some standard.

When a new forecast technique or model is proposed, questions naturally arise about its validity as an operational or theoretical tool. One way to objectively evaluate its performance is through testing to determine its verification statistics. Standards against which the new method are usually compared include chance, persistence, climatology, and already existing techniques.

CHAPTER 3

THE MODEL

A. CONCEPTUAL BASIS

Mesoscale cellular convection associated with cold air outbreaks is the product of air-sea interaction. This phenomenon occurs over the Yellow Sea when marked air-sea temperature contrasts, often exceeding 10°C near the surface, create favorable conditions for Rayleigh convection. Turbulent fluxes of heat and water vapor then modify the entire boundary layer and ultimately give rise to the development of cold air stratocumulus. In most instances, vertical wind shear causes the clouds to appear in longitudinal rolls.

The Rayleigh criterion suggests that atmospheric cellular convection may behave in the same way under certain conditions. From this reasoning comes the conclusion that statistical relationships should exist between cloud amount and certain atmospheric parameters for a given area. These relationships have prognostic value if the relevant atmospheric variables can be predicted numerically.

In selecting variables, one must refer to the classical theoretical studies on cellular convection. Rayleigh showed that cellular convection occurred when the vertical density gradient in the fluid layer exceeded a critical value.

This result can be applied to the atmospheric boundary layer for buoyancy-driven cold-air stratocumulus.

In agreement with theory, a suitable predictor would be one related to the stability of the boundary layer. The temperature lapse rate is often used in diagnosing atmospheric stability, but this parameter is difficult to apply due to the lack of surface temperature observations over the Yellow Sea. Instead, this study uses a boundary layer stability parameter, γ, based on the absolute value of the sea surface-to-850 mb temperature lapse rate. Since the sea surface temperature is warmer than the surface air temperature during cold air outbreaks, this parameter will be greater than the absolute value of the environmental temperature lapse rate. Because the daily variation in sea surface temperature is small, usually less than 0.2°C per day in winter for the Yellow Sea, γ can be determined with relative ease.

In choosing the predictand, one has the option of using either a fixed point or an area method for determining cloud activity. The point method involves a simple yes or no answer to the question of whether or not stratocumulus is present at that location. The area method, which is used in this study, answers the question of how much stratocumulus covers a defined area for a given value of γ at a fixed point.

The "test area" is a 3x3 array of cells, each 1° latitude by 1° longitude, extending from 34 to 37°N and from 123 to 126°E (Figure 6). The fixed point used in the

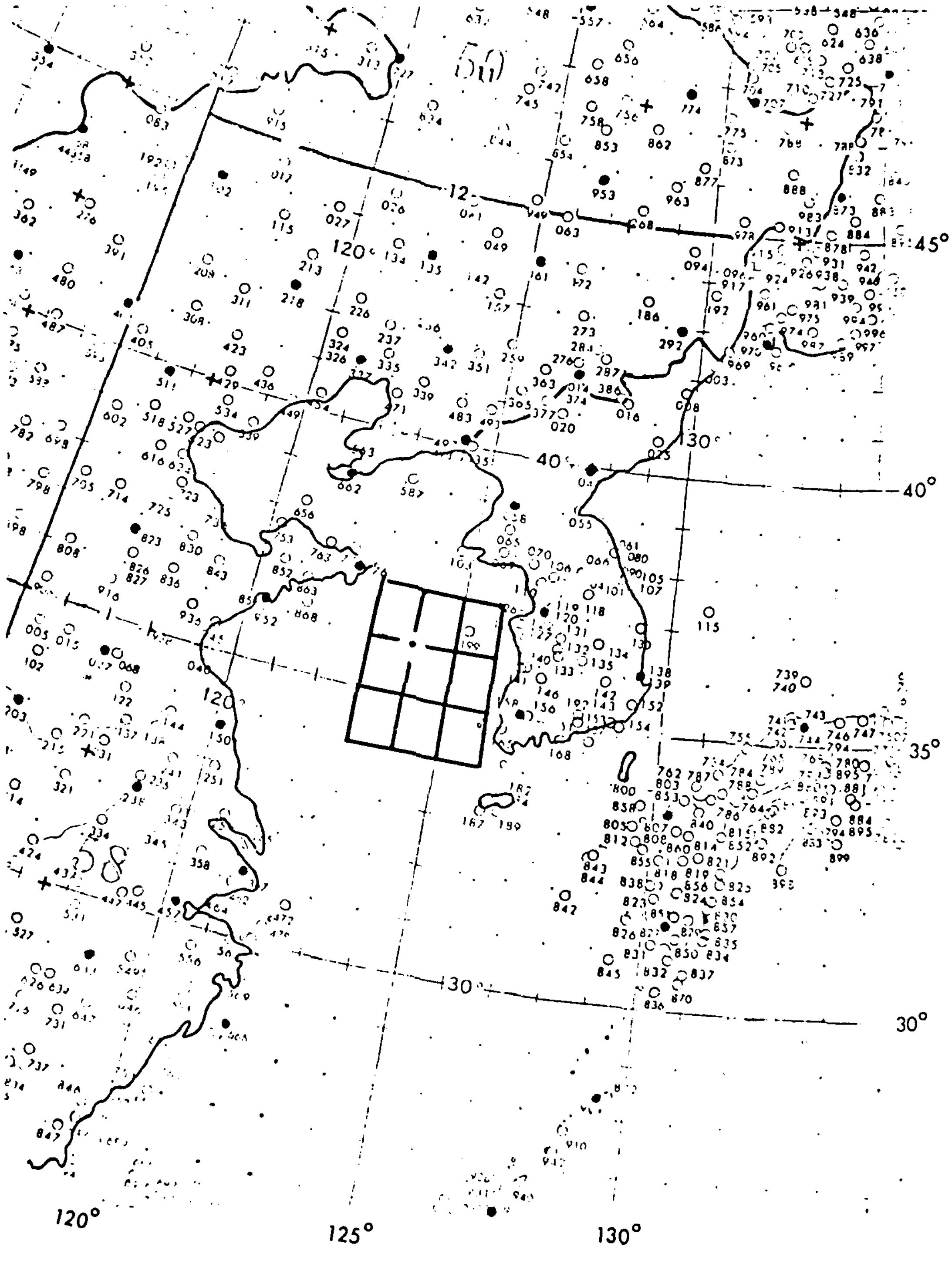

Figure 6. Gridded test area and fixed point used in statistical analyses and model testing.

analysis and testing is at 36°N, 124°E.

Theoretical studies of cellular convection suggest the likelihood of a strong correlation between cloud amount, N, and the stability parameter, γ. However, one can readily imagine conditions when large errors may arise. For example, in cases of very low initial humidity near the top of the boundary layer, the development of clouds would be inhibited. Under these circumstances, clouds would develop slower and would cover less area. On the other hand, if the initial humidity of the continental air is near saturation at the top of the boundary layer, the development of clouds would be enhanced. This would lead to faster cloud development and more areal coverage.

It is therefore necessary to have a predictor related to humidity within the upper part of the boundary layer for analyzing errors from γ. Since typical heights of the cold air stratocumulus cloud layer extend from about 3,000 to 6,000 feet, the 850 mb relative humidity meets this requirement. In practice, this parameter is used in a stepwise manner with the first to provide a set of empirical forecast equations for cloud amount within the test area.

A reliable sample of 850 mb relative humidity data is needed for the analysis of residuals from γ. Unfortunately, the lack of upper air data near the test point impedes the development of a sample that is concurrent with γ and N. Unlike the 850 mb temperature, which has a relatively smooth pattern and can be determined by interpolation within an accuracy of 1-2°C, the dewpoint temperature often varies

greatly over short distances. Thus, interpolated values may lead to large errors in analyzing the relative humidity.

Another approach is to use model output in developing a sample of 850 mb relative humidity data. This method employs the Lagrangian model to forecast relative humidity at the test point. Since the air is usually over land 12 hours before arriving at the test point, the initial 850 mb dewpoint temperature and relative humidity can be analyzed with considerable confidence because of the greater density of upper air observations. A disadvantage of this method is that errors are likely to occur in constructing the forecast trajectory. An advantage is that the relative humidities are derived semi-objectively from model output. They thereby include the effects of those processes causing changes in the moisture content of boundary layer. This method is similar to MOS (Klein and Glahn, 1974).

The use of statistical relationships in predicting cold air stratocumulus requires a means of forecasting the stability parameter and the 850 mb relative humidity. The method used in this research proceeds as follows:

1. Construct the 850 mb trajectory, assuming continuity of major synoptic features.

2. Determine the initial 850 mb and surface temperature and the initial 850 mb and surface mixing ratio in the air column.

3. Determine the gradient in sea surface temperature and the corresponding gradient in saturation mixing ratio along the trajectory.

4. Use the Lagrangian computer model to simulate the changes in γ and RH.

5. Use the empirical equations to forecast cloud amount in the test area.

Figure 7 is a flow diagram showing the main steps of the method.

The following sections discuss the development of the Lagrangian model, beginning with a discussion of the tendency equations for temperature and mixing ratio.

B. TENDENCY EQUATIONS

If ϕ is some atmospheric variable that is a function of horizontal distance, height, and time, the change in ϕ at a fixed point is given by (Holton, 1972)

$$\frac{\partial \phi}{\partial t} = \frac{d\phi}{dt} - \vec{V} \cdot \nabla \phi$$

where $\frac{\partial \phi}{\partial t}$ = the change in ϕ at a fixed point

$\frac{d\phi}{dt}$ = the rate of change of ϕ following the motion

$-\vec{V} \cdot \nabla \phi$ = the advection of ϕ

By substituting for ϕ, the tendency equations can be obtained for temperature and mixing ratio in an air parcel, defined as a collection of air molecules have a mass of 1 kg. Letting T be temperature and r be mixing ratio, these equations are:

$$\frac{\partial T}{\partial t} = \frac{dT}{dt} - \vec{V} \cdot \nabla T$$

and

$$\frac{\partial r}{\partial t} = \frac{dr}{dt} - \vec{V} \cdot \nabla r$$

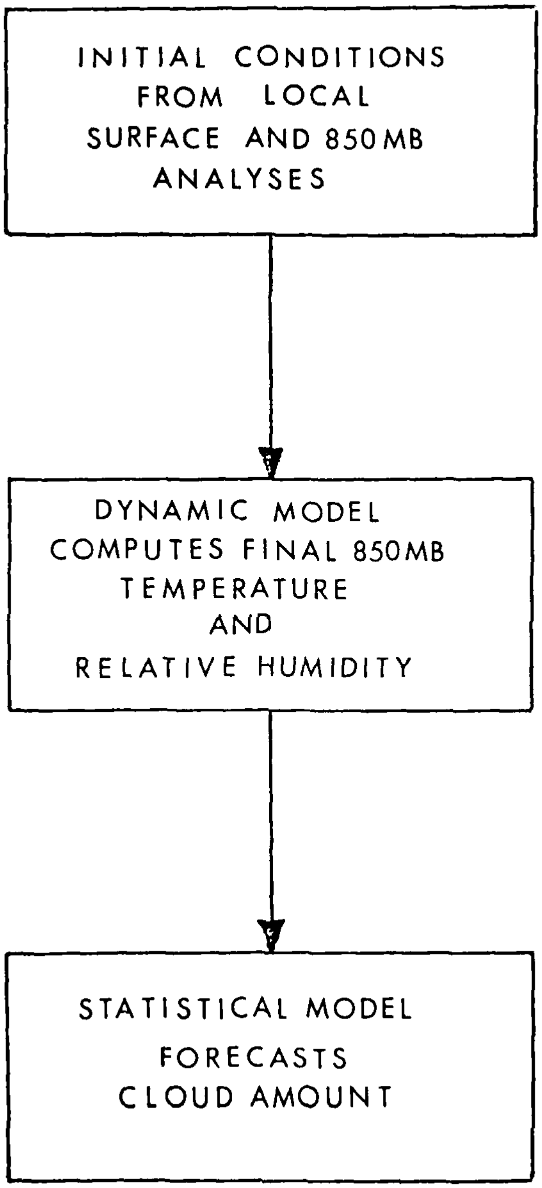

Figure 7. Conceptualization of the three steps in the proposed method for forecasting cold air stratocumulus.

1. Temperature

By separating advection into horizontal and vertical terms and combining the equation of state for an ideal gas with the first law of thermodynamics, the temperature tendency equation can be rewritten as

$$\frac{\partial T}{\partial t} = \frac{1}{C_p}\frac{dH}{dt} - \vec{V}_H \cdot \nabla_p T + w\left[\frac{dT}{dZ} - \frac{\partial T}{\partial Z}\right] + w_e \frac{\Delta\theta}{Z_B}$$

where $\frac{1}{C_p}\frac{dH}{dt}$ = the rate of temperature change due to diabatic heating

$-\vec{V}_H \cdot \nabla_p T$ = the advection of temperature on a constant pressure surface

$w\left[\frac{dT}{dZ} - \frac{\partial T}{\partial Z}\right]$ = the temperature change due to vertical motion

$w_e \frac{\Delta\theta}{Z_B}$ = the temperature change due to entrainment of air through the inversion

In this equation, C_p is the specific heat of dry air at constant pressure, H is heat, V_H is the horizontal wind, w is the large scale vertical velocity, dT/dZ is the dry adiabatic lapse rate, $\partial T/\partial Z$ is the environmental lapse rate, w_e is the entrainment rate of air through the capping inversion, $\Delta\theta$ is the jump in potential temperature across the interface at the top of the boundary layer, and Z_B is the height of the boundary layer.

The diabatic processes causing temperature changes in the parcel are sensible heating, latent heating, and radiative heating or cooling. The surface flux of sensible heat is specified by the bulk aerodynamic method as (Chou and Atlas, 1982)

$$\left[\frac{dH}{dt}\right]_S = \rho\ C_p\ C_D\ (\bar{T}_s - \bar{T}_a)\ \bar{U}_a/Z_B$$

where ρ is the air density, C_D is the bulk transfer coefficient, $\bar{U}$ is the mean wind speed near the surface, T_s is the sea surface temperature, T_a is the air temperature near the surface. This study follows Chou and Atlas (1982) in using a value of 1.5×10^{-3} for C_D (after Kondo, 1975).

The latent heating in the cloud layer is

$$\left[\frac{dH}{dt}\right]_L = Z_c\ L\ \frac{dr}{dt}/Z_B$$

where L is the latent heat of condensation, Z_c is the thickness of the cloud layer, and dr/dt is the rate of condensation of water vapor into liquid.

The heat flux due to radiation is expressed as

$$\left[\frac{dH}{dt}\right]_R = \beta\ F_N/Z_B$$

where F_N is the net radiative flux of the boundary layer and β is the mechanical equivalent of heat. F_N is expressed over an area of variable sky conditions as

$$F_N = a_1F_x + a_2F_o$$

where F_x and F_o denote the net fluxes for the cloudy and clear areas respectively, and a_1 and a_2 are the weights assigned to each area. F_x is broken into its individual constituents to give

$$F_x = F_S - F_L - F_U - F_A$$

where F_S = the upward flux due to longwave radiation from the sea surface

F_L = the downward flux due to radiation from the cloud base

F_U = the upward flux due to radiation from the cloud top

F_A = the downward flux from the free atmosphere

The constituents of F_o are written as

$$F_o = F_S - F_A$$

From the Stefan-Boltzman law for blackbody radiation, each flux is expressed as

$$F_i = \sigma T_i^4$$

where T_i is the temperature of the i-th constituent and σ is the Stefan-Boltzman constant.

The temperature change due to diabatic processes is therefore

$$\frac{dT}{dt} = \frac{1}{C_p}\frac{d}{dt}\left[H_S + H_L + H_R\right]$$

For simplicity, the temperature advection is converted to natural coordinates by

$$-\vec{V}_H \cdot \nabla_p T = -V_{\hat{s}} \cdot \frac{\partial T}{\partial s}\hat{s}$$

where $\partial T/\partial s$ is the temperature gradient along the trajectory.

The change in temperature associated with adiabatic warming or cooling caused by large scale vertical motion is obtained from

$$\left[\frac{dT}{dt}\right]_w = w\left[\frac{dT}{dt} - \frac{\partial T}{\partial z}\right]$$

In this equation the amount of temperature change depends upon the environmental lapse rate and the magnitude of w. For example, if the environmental lapse rate is small and there is rising motion, then cooling will occur at a constant pressure level such as 850 mb.

The temperature change due to entrainment is

$$\left[\frac{dT}{dt}\right]_E = w_e \frac{\Delta\theta}{Z_B}$$

where w_e is the entrainment rate, $\Delta\theta$ is the jump in potential temperature across the capping inversion, and Z_B is the depth of the boundary layer. This equation is adopted from Stage and Businger (1981). If an inversion caps the layer, $\Delta\theta$ is positive and entrainment causes warming.

2. Mixing Ratio

Processes contributing to changes in the mixing ratio of an air parcel include surface evaporation, condensation, and entrainment. The surface flux of water vapor is specified by the bulk aerodynamic method as

$$\left[\frac{dr}{dt}\right]_Q = \rho\ L\ C_D\ (\bar{r}_s - \bar{r}_a)\ \bar{U}_a/Z_B$$

where r_s is the saturation mixing ratio corresponding to the sea surface temperature and r_a is the mixing ratio of air at the surface. At the cloud condensation level (CCL), some of the water vapor is changing phase to the liquid state. This process decreases the mixing ratio of the air parcel. If the rate of water vapor condensation is $\delta r/\delta t$ then the change in

mixing ratio of the parcel is given by

$$\left[\frac{dr}{dt}\right]_L = \frac{\delta r}{\delta t}/Z_B$$

The stable layer above the boundary layer has a much smaller mixing ratio than the cloud layer. Thus, entrainment of air through the interface causes a decrease in mixing ratio within the boundary layer. This change in r for a parcel at a fixed pressure level is

$$\left[\frac{dr}{dt}\right]_E = w_e \frac{\Delta r}{Z_B}$$

where Δr is the "jump" in r across the interface.

C. LAGRANGIAN FORECAST MODEL

1. Purpose

The Lagrangian forecast model simulates changes in the temperature and mixing ratio at the surface and at the top of the boundary layer along a trajectory describing the mean flow of the layer. The final values are used in computing γ and RH for the empirical forecast equations.

2. Assumptions and Approximations

For most processes, available data are combined with theory and/or the results of other studies to make simplifying assumptions and approximations. The sensitivity of the numerical results to approximations regarding cloud layer thickness, boundary layer growth, entrainment rate, solar heating, radiative cooling, and vertical velocity are given in Appendix F. The following is a list of assumptions and

approximations. For clarity, each is stated concisely and, if necessary, is followed by a justification or explanation.

1. The boundary layer is well mixed and has a characteristic structure including:

    a. A layer of absolute instability from the surface to 10 m.

    b. A dry adiabatic lapse rate from 10 m to the CCL.

    c. A moist adiabatic lapse rate through the cloud layer.

    d. An inversion capping the boundary layer.

These follow from Burke (1945), Haltiner and Martin (1957), and Figure 5 in Chapter 2.

2. Clouds form when the relative humidity at the top of the boundary layer is greater than or equal to 80%.

This value is the one that is typically used in forecast centers.

3. The cloud layer thickness is approximated from the 850 mb relative humidity as:

    a. 300 m if $80\% \geq RH \leq 85\%$

    b. 600 m if $85\% < RH \leq 90\%$

    c. 900 m if $RH > 90\%$

    d. If $RH \geq 100\%$ the cloud layer thickness increases at the same rate as that of the height of the boundary layer.

These estimates are derived from a Skew T, log p diagram and upper air soundings. The upper and lower limits are subjectively based on observations of cold air stratocumulus along the west coast of Korea. The range of relative humidity assigned to each thickness was determined from the thermodynamic diagram. In the model, the upper limit is

exceeded only by a precipitating cloud layer. Observations show that the actual thickness may vary by several hundred meters in some cases. However, the sensitivity of the numerical results to these variations is small (Appendix F).

4. The growth of the boundary layer is estimated from γ as:

   a. 5 m/hr if $8°C/km < \gamma \leq 9°C/km$

   b. 7.5 m/hr if $9°C/km < \gamma \leq 10°C/km$

   c. 10 m/hr if $\gamma > 10°C/km$

These rates are obtained from upper air soundings.

It is assumed that the growth rate will be related to the boundary layer stability parameter. Soundings from Osan AB and Kagoshima are used in analyzing the slope of the boundary layer inversion. This slope is divided by the 850 mb wind speed to determine the rate of growth of the boundary layer. Growth rates are stratified according to γ. Although actual growth rates may be as large as 50 m/hr, the sensitivity of the numerical results to a rate of this magnitude is small (Appendix F).

5. The initial height of the boundary layer is the 850 mb height.

This estimate is based on upper air soundings from Osan AB and Kwangju showing the top of the boundary layer to typically be near the 850 mb level during cold air outbreaks. The data indicate departures of up to 400 m in some cases although a more common value is 200 meters or less.

6. Precipitation occurs if the 850 mb relative humidity exceeds 100%.

7. Latent heating from condensation in the cloud layer is mixed throughout the boundary layer.

8. The absorption of solar radiation produces heating of 0.3°C per day and is the same for both cloudy and clear skies.

Some models neglect the effects of solar radiation (e.g., Stage and Businger, 1981). Although the effects are small compared to other energy transfer processes, warming of 0.3 to 0.6°C can occur (Charney, 1945). The lower value is used in this model due to the time of year. Sensitivity testing of higher values shows the effect on the numerical results to be small (Appendix F).

9. Radiative cooling of the boundary layer under clear sky conditions is 1.0°C per day.

Charney (1945) indicated that cooling of 1 to 3°C per day will occur in the free atmosphere due to longwave radiational cooling. The highest values occur in the tropics and the lowest in the polar regions. The lower value is used in this model due to the location and time of year. Sensitivity testing of higher values shows the effect on the numerical results to be small (Appendix F).

10. Radiative cooling of the cloud layer occurs entirely within the boundary layer.

11. The radiative temperature of the top of the cloud layer is the 850 mb temperature. The radiative temperature of the cloud base is determined by assuming a moist adiabatic lapse rate through the cloud layer.

12. The net radiative cooling of the boundary layer is a weighted average of the cloudy and cloud-free areas. For cold air stratocumulus these weights are assumed to be 0.8 for the cloudy area and 0.2 for the clear area.

These values are determined from analysis of satellite pictures (Figure 3). The imagery often shows that the stratocumulus cloud field has alternating cloudy and clear areas due to its banded structure. It is subjectively estimated that in most cases the clouds occupy 80% of the total area.

13. The jump in potential temperature across the interface at the inversion is 1°C.

This value is derived from upper air soundings.

14. The jump in mixing ratio across the interface at the inversion is initially 0.25 g/kg.

This value is derived from upper air soundings.

15. The 850 mb height of the air column is constant.

16. The entrainment rate is approximated from γ and RH as shown in Figures 8 and 9. The maximum entrainment condition applies if clouds are present while the minimum condition applies under clear skies.

These rates are comparable to those of Deardorff (1976). It is assumed that the energy available for entrainment will increase with γ. Thus, the entrainment rate is scaled according to γ and increases as the boundary layer becomes more unstable. The 850 mb relative humidity is highly sensitive to entrainment rate (Appendix F). However, it is important to note that the values used in the model give point cloud forecasts that agree well with the satellite cloud imagery. Entrainment will be discussed in more detail later in this section.

17. The vertical velocity is estimated from map typing (Appendix A).

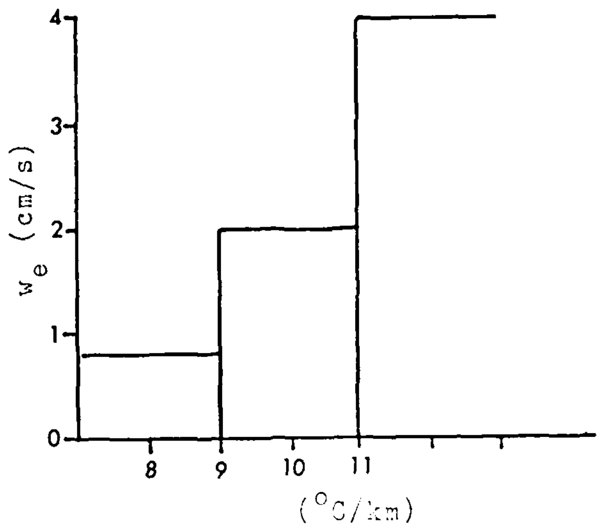

Figure 8. Approximation of entrainment rate (w_e) from the stability parameter for maximum entrainment conditions (RH 80%).

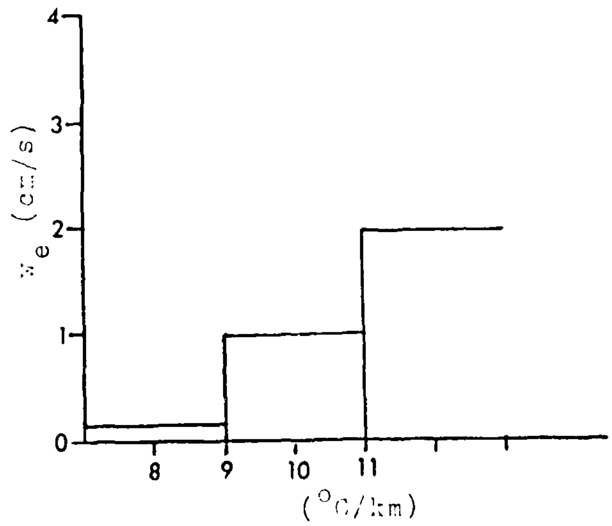

Figure 9. Approximation of entrainment rate (w_e) from the stability parameter for minimum entrainment conditions (RH 80%).

The 850 mb temperature is highly sensitive to vertical velocity (Appendix F).

3. Entrainment

Entrainment is driven by turbulence kinetic energy (TKE) produced by buoyancy fluxes in the mixed layer as it warms over water (Stage and Businger, 1981). Deardorff (1976) lists surface heat fluxes, cloud top radiative cooling, solar heating, changes in cloud thickness, and strength of the inversion as important factors in determining TKE and the rate of entrainment. Increasing buoyancy implies increasing instability and a decreasing lapse rate in the mixed layer. Thus, one concludes that the entrainment rate will be related to γ.

Deardorff (1976) gives examples of the maximum and minimum entrainment rates associated with certain surface heat fluxes. He uses a maximum entrainment rate for cloudy conditions and a minimum rate for clear skies. Following the results of Deardorff, this model roughly approximates the entrainment rate from γ as:

1. Weak entrainment if γ is greater than -9°C/km.
2. Moderate entrainment if γ is less than or equal to -9°C/km and greater than or equal to 11°C/km.
3. Strong entrainment if γ is less than -11°C/km.

The above ranges are based on analysis of satellite data for the Yellow Sea during the winter of 1981-1982. Cases were subjectively grouped according to lapse rate and cloud field size as seen on the satellite pictures. Table 1 shows the

maximum and minimum rates assigned to each category of entrainment. These magnitudes are comparable to Deardorff's (1975).

Table 1

Method of Approximating Entrainment Rate

Degree	γ °C/km	Minimum cm/s	Maximum cm/s
Weak	-9	0.2	0.8
Moderate	-9 to -11	1.0	2.0
Strong	-11	2.0	4.0

4. Large-Scale Vertical Motion

Large-scale vertical motion associated with synoptic scale weather systems may sometimes cause adiabatic cooling or warming in air parcels and changes in temperature on a constant pressure surface. Using the relationship

$$\frac{\Delta T}{\Delta t}\,\delta t = w\left(\frac{dT}{dZ} - \frac{\partial T}{\partial Z}\right)\delta t$$

and assuming an environmental lapse rate of -6°C/km and a vertical velocity of 1.0 cm/s shows that hourly cooling of about 0.14°C is possible at a constant pressure level. These conditions are typical for middle latitude cyclones of moderate intensity. The temperature change associated with subsidence in anticyclones is much smaller. Taking a typical anticyclone value of 0.3 cm/s for vertical motion and a lapse rate of -6°C/km shows hourly warming of just 0.03°C at a constant pressure level.

Map typing is used in this research for estimating the vertical velocity. This method assumes that the atmosphere will have similar vertical velocities in systems showing similar characteristics. The map types are taken from case studies of systems affecting the Yellow Sea region during the winter of 1981-1982. The adiabatic method is used to diagnose the magnitude of the vertical motion. These maps are shown in Appendix A.

5. Numerical Methods

The first order differential equation

$$\frac{d\phi}{dt} = f(\phi,t)$$

can be solved by finite difference methods. The simplest of these is a first-order Runge-Kutta technique, also known as the Euler method, giving the solution as

$$\phi_i^1 = \phi_i + \phi_i^1 \Delta t$$

where $\phi_i^1 = f(\phi_i, t_i)$. Although truncation errors may cause this method to be unstable in some physical applications, it is found to be acceptable in this model for forecasting temperatures and relative humidities. It also has the advantage of being a one-step method; i.e., to find ϕ_{i+1} it only needs the information from the preceding point ϕ_i, t_i. An in-depth description of the Euler method may be found in McCracken and Dorn (1964) or in Peckham (1971).

The tendency equations for the 850 mb temperature and mixing ratio are integrated over 1-hour time increments.

During this process, the model is simulating the changes in these variables as the air column proceeds from point to point along its trajectory. The equation for the temperature change at 850 mb is

$$\frac{dT}{dt} = f(T,t)$$

and the Euler method solution

$$T_{i+1} = T_i + T_i^1 \Delta t$$

where T_i^1 is the hourly change in T caused by sensible heating, latent heating, radiative exchanges, vertical motion, and entrainment.

The equation for the 850 mb mxing ratio is

$$\frac{dr}{dt} = f(r,t)$$

and the solution is

$$r_{i+1} = r_i + r_i^1 \Delta t$$

where r_i^1 is the hourly change in r caused by surface evaporation, condensation in forming clouds, and entrainment.

The finite difference equation for the change in temperature due to sensible heating is

$$\left[\frac{\Delta T}{\Delta t}\right]_s \delta t = \frac{\bar{U}\rho\ C_D}{Z_B} \left[(T_s + \tilde{U}\ \frac{\Delta T_s}{\Delta n}) - (T + \frac{\Delta T}{\Delta t}\right] \delta t$$

where $\Delta T_s/\Delta n$ is the sea surface temperature gradient. The equation for the change in mixing ratio due to surface evaporation is

$$\left[\frac{\Delta r}{\Delta t}\right]_Q \delta t = \frac{\bar{U}\rho\ C_D}{Z_B}\left[\left(r_s + U\frac{\Delta r_s}{\Delta n}\right) - \left(r + \frac{\Delta r}{\Delta t}\right)\right]\delta t$$

where $\Delta r_s/\Delta n$ is the mixing ratio gradient corresponding to the sea surface temperature gradient.

At each time step the saturation mixing ratio for 850 mb is calculated by

$$q_s = \frac{0.622\ e_s}{p-e_s}$$

where p equals 850 mb and e_s is the saturation vapor pressure obtained from

$$e_s = 6.11 \exp\left[\frac{L}{R_m}\left(\frac{1}{273.15} - \frac{1}{T+273.15}\right)\right]$$

with R_m being the gas constant for moist air. The 850 mb relative humidity is then given by

$$RH = \frac{r}{r_s} \times 100$$

D. STATISTICAL-DYNAMICAL FORECAST MODEL

1. Purpose

The statistical-dynamical model, comprised of the Lagrangian model and the statistical relationships using γ and RH, forecasts N for the defined test area. The forecast is made in two steps. First, the cloud amount is forecast from γ. This forecast is then corrected based on RH.

2. Assumptions

The following assumptions are made in the statistical model:

1. If N forecast from γ is greater than 9, then the forecast is 9. If the forecast N based on γ is less than 0 then the forecast is 0.

2. If the final N forecast after applying the correction is greater than 9, then the forecast is 9. If the final N is less than 0 then the forecast is 0.

3. Empirical Equations

The empirical forecast equations each require only one predictor. The equation for N from γ has the form

$$N = \frac{\gamma - b\ (\bar{\gamma} - \bar{N})}{b}$$

where N = cloud amount

γ = boundary layer stability parameter

$\bar{\gamma}$ = mean boundary layer stability parameter

$\bar{N}$ = mean cloud amount

b = slope of the line of regression

The equation for the error in cloud amount, ΔN, from RH is

$$\Delta N = \frac{RH - b\ (\overline{RH} - \overline{\Delta N})}{b}$$

where ΔN = the error in N

RH = 850 mb relative humidity

$\overline{RH}$ = mean 850 mb relative humidity

$\overline{\Delta N}$ = mean error in N

b = slope of line of regression

The final forecast equation for N is

$$N = N_1 + \Delta N_1 \quad .$$

CHAPTER 4

DATA AND ANALYSIS

A. DESCRIPTION OF TEST AREA

The Yellow Sea is an excellent location for a statistical analysis of mesoscale cellular convection. During the period dominated by the northwest winter monsoon there are frequent outbreaks of cP air, accompanied by cold-air stratocumulus. Analysis of the atmospheric conditions is aided by a dense network of surface synoptic and upper air observing stations (Figure 10). Furthermore, the daily change in sea surface temperature is small, most likely a consequence of the relatively weak currents in the Yellow Sea.

Geographically, the Yellow Sea is a large shallow inlet of the Pacific Ocean. Bordering Korea on the east, China on the north and west, and merging with the East China Sea in the south, it has a surface area of about 100,000 km^2 and a maximum depth of about 75 meters. A more detailed description of the region is found in the U.S. Navy TR 77-03 (1977).

Appendix A represents the climatology of the monthly mean sea surface temperatures of the Yellow Sea for September through March (U.S. Navy, 1977; U.S. Air Force). Surface currents change from southerly to northerly during the winter monsoon. Enhanced infrared satellite imagery from the

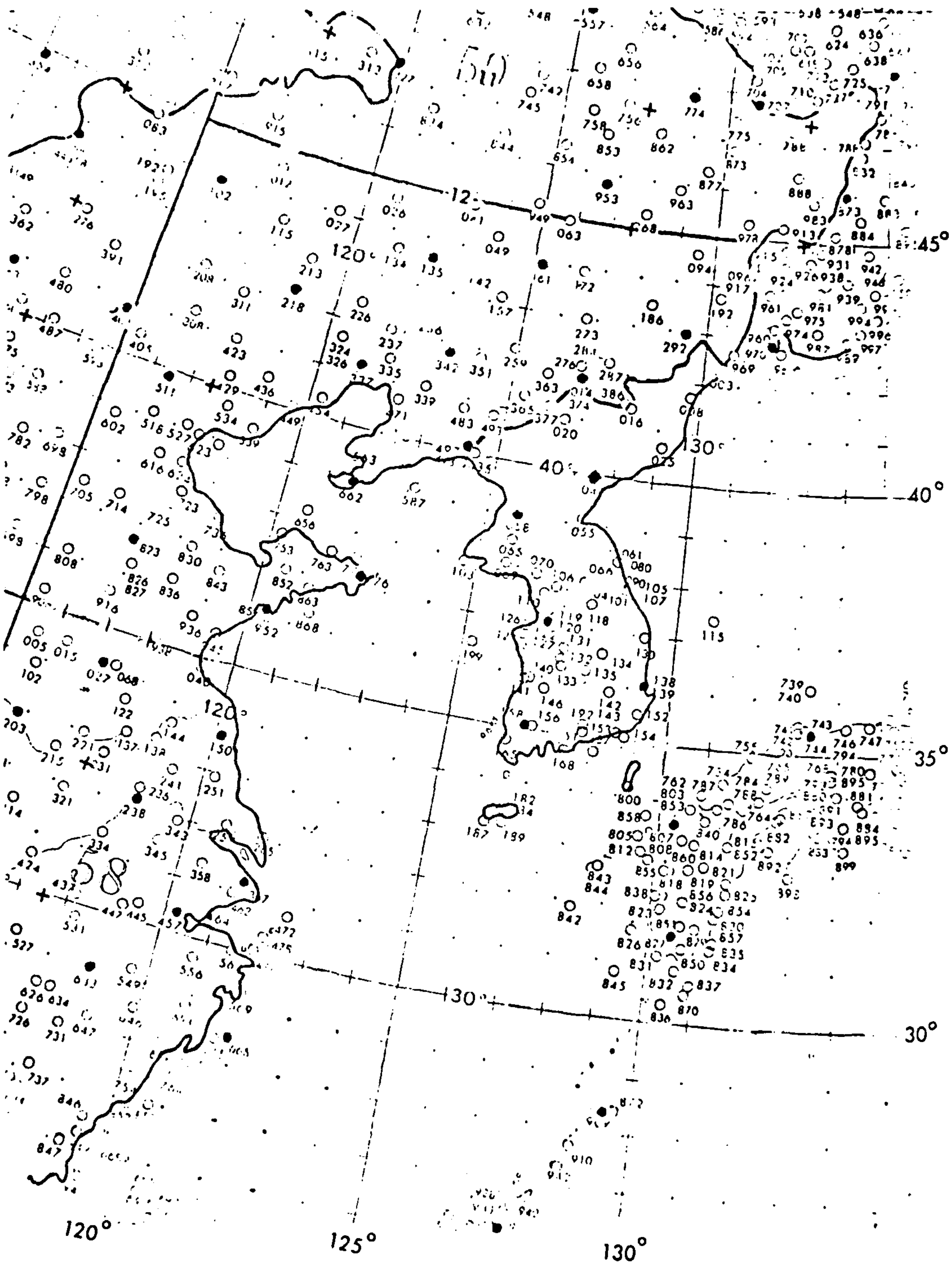

Figure 10. Network of upper air observing stations surrounding the Yellow Sea (stations denoted by ●).

winter of 1981-1982 shows a sea surface temperature gradient closely resembling that of climatology in both pattern and magnitude. Ship reports are used as an additional check on the variation of sea surface temperatures from climatology. The temperatures are found to be as much as 4°C warmer than climatology for the East China Sea and in the extreme southern edge of the Yellow Sea. However, the temperatures inside the study area are within 1°C of the climatological value in 5 of the 6 reports available. It is, therefore, assumed that sea surface temperature climatology is satisfactory for this study.

Figure 6 depicts the gridded area used for statistical analysis and model testing. Comprised of a 3x3 array of 9 grid cells, each measuring 1° latitude by 1° longitude, the area extends from 34 to 37°N and from 124 to 127°E. A fixed point at 36°N, 125°E is chosen for evaluation of N, γ, and RH. A larger test area is not considered because time and space variations caused by the larger atmospheric flow will adversely affect the empirical forecast relationships.

B. ANALYSIS OF SATELLITE DATA

This research uses satellite imagery from the Defense Meteorological Satellite Program (DMSP) site at Osan AB, Korea. It consists entirely of direct readout imagery from NOAA-6 and NOAA-7, both polar orbiting, sun-synchronous satellites. NOAA-6 imagery approximately coincides with

0000Z and 1200Z compared to 0600Z and 1800Z for NOAA-7.

Both visual and infrared (IR) data are used in the analysis. Cold air stratocumulus shows little difference in total cloud area on the IR compared to the visual imagery, despite being a low cloud type. On the IR pictures, these clouds appear in a light gray shade because of the large contrast in temperature between the cold cloud tops and the warm sea surface. Often this temperature difference exceeds 20°C. Figures 11-12 provide a comparison of cold-air stratocumulus in the visual and IR modes.

The nominal resolution of the visual and IR sensors on NOAA-6 and NOAA-7 is about 0.5 nautical mile at subpoint. However, the actual resolution on the direct readout imagery is a function of:

1. Sensor lens and/or mirror aberrations.
2. Detector characteristics.
3. Frequency response of the sensor electronics.
4. Smear due to image motion.
5. Tape recorder characteristics (if not direct readout).
6. Communications.
7. Ground station characteristics and maintenance.
8. Altitude of satellite.
9. Relative contrast between object and the background.
10. Alignment of the object to the scan line.

Figure 11. Infrared satellite picture from NOAA-6 on 1 December 1981 at 0000 GMT (descending node at 114.5°E). Low stratocumulus clouds over the Yellow Sea appear in a light gray shade because of the large temperature difference between the cloud tops and sea surface.

Figure 12. Visual satellite picture [illegible] December 1981 at 0000 GMT [illegible] (11.5 D). The areal extent [illegible] the [illegible] in the [illegible]

All direct readout data are rectified by the Data Display Segment System, but the rectification process does not improve spatial resolution (U.S. Air Force, 1974).

A gridded acetate overlay is used in analyzing cloud amount from the satellite imagery. On each picture, the number of grid cells containing part of a stratocumulus cloud field is counted manually. Spacing between individual cloud lines or cloud elements, in addition to any part of the cloud field falling outside the gridded array, is disregarded. Cloud amounts are determined to the nearest half-square, i.e. a half-square counts as 0.5.

C. ANALYSIS OF SURFACE AND UPPER AIR DATA

The surface and upper air data used in the statistical analysis come exclusively from the Daily Weather Maps and Synoptic Data Tabulations published monthly by the Japan Meteorological Agency (1981, 1982). From these analyses, the 850 mb temperature and height are determined for the test point and are used along with the sea surface temperature from the climatological maps in computing γ from

$$\gamma = \left| \frac{T_8 - T_s}{Z} \right|$$

where T_8 is the 850 mb temperature, T_s is the sea surface temperature, and Z_8 is the 850 mb height.

The Lagrangian model computes RH for analysis of the residuals from γ. Initial conditions for the model are taken from the surface and 850 mb charts. The procedure includes 9 steps:

1. Analyze the 850 mb heights, temperature, and dewpoint depression.

2. Determine the 850 mb geostrophic wind speed and direction upstream from the test point.

3. Construct the forecast trajectory of the 850 mb air parcel arriving at the terminal point 12 hours later.

4. Plot and analyze the surface temperatures and dewpoint temperatures near the initial point of the trajectory. Determine the initial surface temperature and mixing ratio of the column.

5. Determine the sea surface temperature gradient along the trajectory.

6. Determine the mixing ratio gradient correspond- to the sea surface temperature gradient along the trajectory.

7. Determine the time in hours that the air column will be over water.

8. Determine the initial 850 mb temperature and mixing ratio of the column.

9. Enter all input parameters and run the numerical model.

This method assumes that the initial column of air from the surface to the top of the boundary layer moves as one unit and that the speed and direction of the unit are approximately that of the 850 mb geostrophic wind. Furthermore, it is assumed that this same wind speed is satisfactory for the bulk equations used in computing surface fluxes.

Figure 13 shows an idealized sounding of the temperature and dewpoint temperature in the marine boundary layer before and after air-sea interaction. This figure is based on Burke (1945). Haltiner and Martin (1957), and on observations from upper air soundings from Korea and Japan. The sounding represented by the dashed lines gives the initial

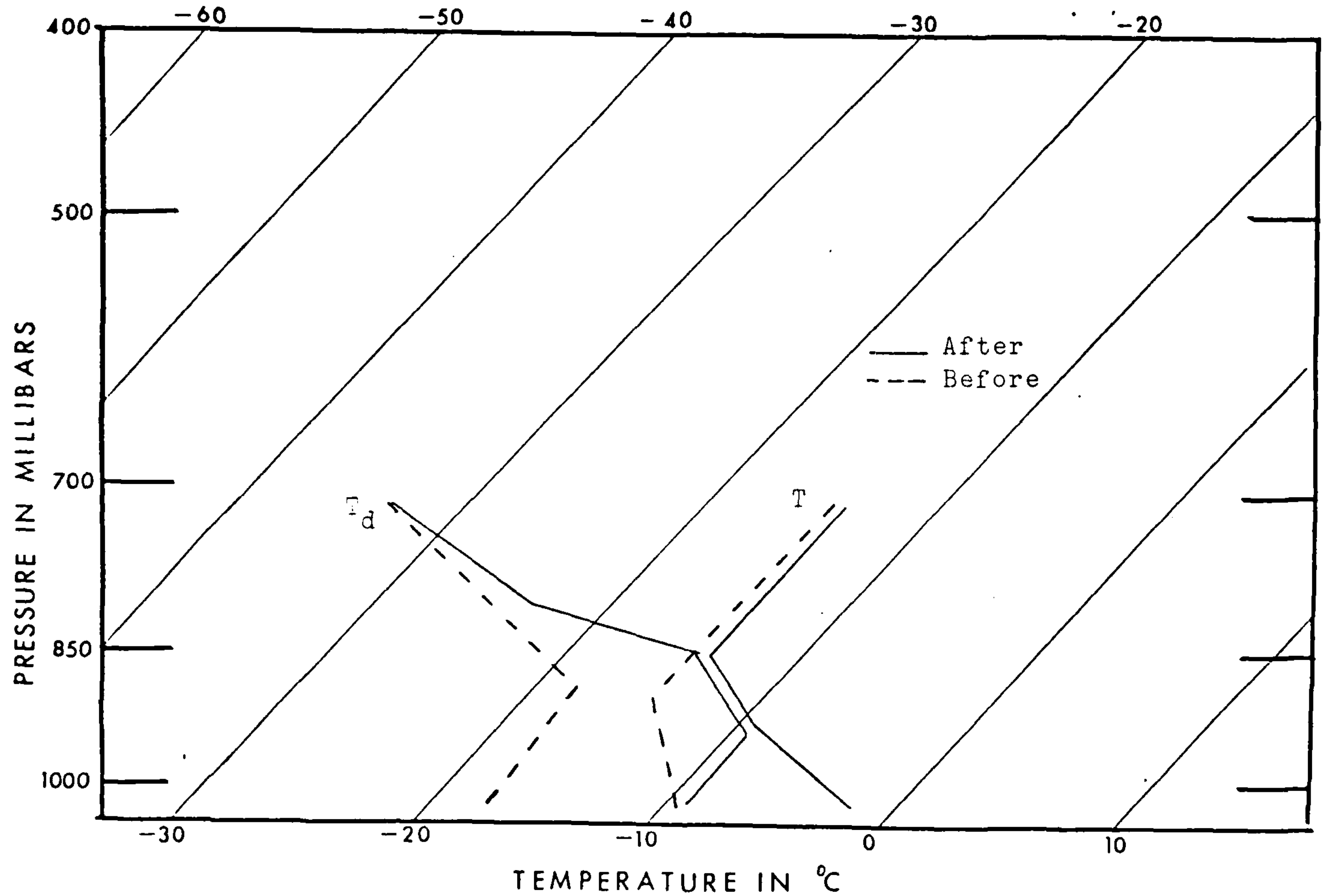

Figure 13. Representation of idealized soundings showing the structure of the atmospheric boundary layer before and after the modification of continental polar air to maritime polar air.

sounding over land while the sounding represented by solid lines is that following modification by air-sea interaction. Many of the soundings shown in Appendix D are similar to the idealized sounding following modification over water.

D. STATISTICAL ANALYSIS

1. Purpose

Satellite pictures provide considerable information on the extent of cold-air stratocumulus. This study seeks to relate significant properties of the boundary layer environment to the cloud amount observed on satellite imagery of the gridded test area. The objective is the development of statistical forecast equations for N.

This section also presents probabilities of clouds covering the entire test area, the probabilities of the error from γ being positive or negative, frequency distributions of cloud amount and histograms for each cloud outbreak period for the winter of 1981-1982.

2. Linear Regression Analysis

Ideally, physical reasoning contributes to the selection of variables for linear regression analysis. Since buoyancy-driven Rayleigh convection is the physical process associated with cold-air stratocumulus, reasoning suggests that cloud activity will be related to parameters that describe atmospheric stability. Hence, the use of γ as an independent variable is supported by the theory of Rayleigh

convection.

Linear regression analysis is used in determining the relationship between N and γ. The analysis is confined to days when N is greater than 0 but less than 9. This restriction reduces the sample to 93 cases with N ranging from 0.5 to 8.5. Data for the entire period are represented in Appendix C where N_γ is the cloud amount from the regression equation for γ and ΔN is the error, $N_\gamma - N$. The cases used in the regression analysis are denoted by an asterisk (*).

Figure 14 shows the scatter diagram of N and γ. Also given are the line of regression, fitted by least squares, and the lines of scatter. There is a positive correlation between N and γ as required by the Rayleigh criterion. The equation for the line of regression is

$$N = 2.158\gamma - 17.067$$

A correlation coefficient, $r_{\gamma \cdot N}$, of 0.65 suggests a strong relationship between N and γ. The significance of this correlation coefficient is tested by comparing its absolute value to the absolute value of 2.6 σ_r. σ_r is the standard deviation of the correlation coefficients of all possible samples containing n pairs of observations and is computed from the formula

$$\sigma_r = (n - 2)^{0.5}$$

Since $r_{\gamma \cdot N}$ is much greater than the absolute value of σ_r (0.1048) the probability of this coefficient originating

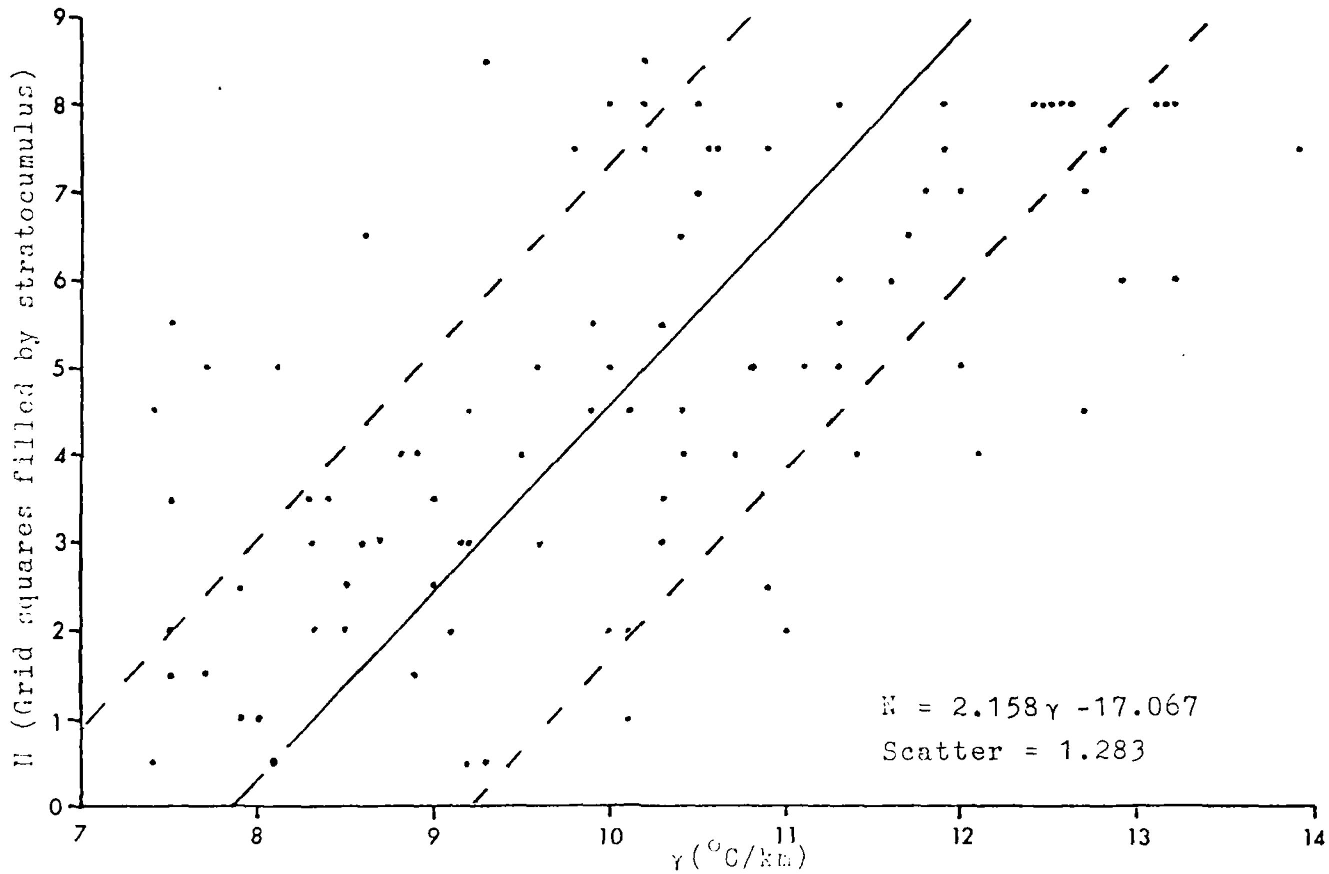

Figure 14. Scatter diagram and linear regression analysis of cloud amount (N) and stability parameter (γ).

from uncorrelated populations is less than 1% (Panofsky and Brier, 1968).

The scatter of N is computed from the formula (Panofsky and Brier, 1968)

$$S_{N\cdot\gamma} = (S_N^{\ 2} - b_{N\cdot\gamma}^{\ \ 2}\ S_\gamma^{\ 2})^{0.5}$$

where S_N is the standard deviation of N, $b_{N\cdot\gamma}$ is the slope of the line of regression, and S_γ is the standard deviation of γ. About 68% of the observations of N fall within the lines of scatter in Figure 14.

Despite the strong correlation between N and γ, $r_{\gamma\cdot N}$ accounts for just 42.3% of the variance. Figure 15 gives the frequency distribution of the errors from γ for a class interval of N=2. Most of the errors fall within a range of N = $\pm$ 3. From physical reasoning one would expect the outlying errors to be related to humidity near the level of cloud development. For the 37 cases showing the largest error, model output for the 850 mb relative humidity (RH) is used in analyzing the residuals. It is found that the regression equation for γ over-predicts N for cases having low RH and under-predicts N for cases having high RH. Table 2 lists the model output data for the analysis of the residuals.

The error, ΔN, obtained from the equation for γ and from N observed on the satellite pictures, is analyzed by linear regression to determine the influence of RH on the cloud field. Figure 16 is a scatter diagram of ΔN and RH.

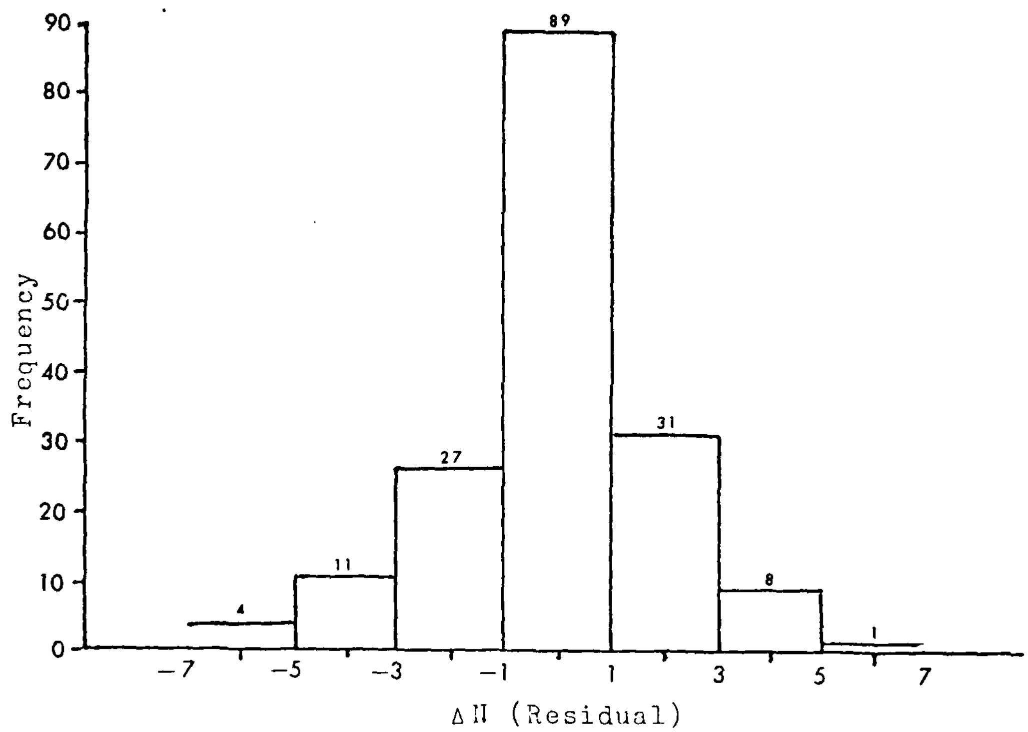

Figure 15. Frequency distribution of the residuals of N from the regression equation for N and γ.

Table 2. Data for analysis of residuals using model output for 850 mb relative humidity (RH).

γ	N_m	N_o	ΔN	RH
10.4	4.4	2.0	2.4	72.2
8.4	0.3	0.5	-0.2	79.8
10.5	4.6	7.0	-2.4	77.0
7.7	0.0	5.0	-0.5	94.6
9.7	2.9	2.0	0.9	75.7
9.4	2.3	2.0	0.3	77.7
9.0	1.5	6.0	-4.5	97.8
10.9	5.4	2.5	2.9	56.4
10.7	5.0	4.5	0.5	64.3
13.3	9.0	5.0	4.0	60.1
9.3	2.1	0.5	1.6	70.8
8.8	1.1	3.0	-1.9	84.9
9.8	3.1	8.0	-4.9	85.7
9.0	1.5	4.0	-2.5	96.0
10.1	3.8	6.0	-2.2	80.8
11.5	6.6	6.5	0.1	75.0
11.3	6.2	6.0	0.2	65.2
8.7	0.9	8.0	-7.1	96.0
11.2	6.0	2.5	3.5	60.7
9.6	2.7	1.0	1.6	71.9
9.5	2.5	6.0	-3.5	86.2
8.7	0.9	3.0	-2.1	84.9
9.4	2.3	4.5	-2.2	75.6
11.8	7.2	8.0	-0.8	70.7
10.4	4.4	1.0	3.4	66.8
8.8	1.1	2.0	-0.9	76.7
7.8	0.0	6.0	-6.0	92.2
10.4	4.4	8.0	-3.6	97.4
10.6	4.8	5.0	-0.2	73.8
11.9	7.4	8.0	-0.6	76.1
10.4	4.4	1.5	2.9	64.0

Table 2 (cont.)

γ	N_m	N_o	ΔN	RH
10.7	5.0	5.0	0.0	71.5
10.6	4.8	8.0	-3.2	73.1
9.0	1.5	3.0	-1.5	75.5
12.5	8.7	5.0	3.7	76.8
10.8	5.2	3.5	1.7	63.6
9.6	2.7	8.0	-5.3	90.2

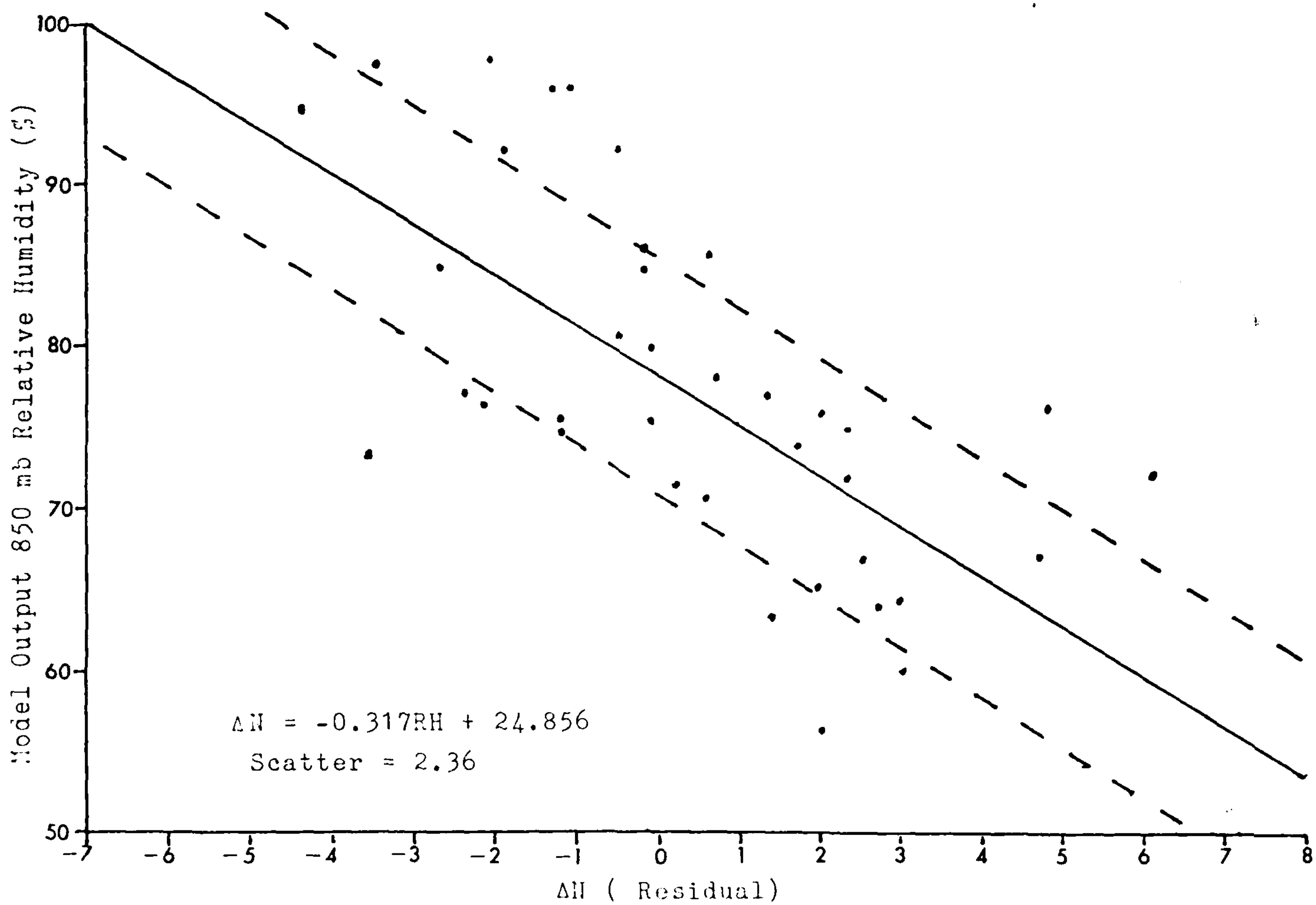

Figure 16. Scatter diagram and linear regression analysis of cloud amount residuals (ΔN) and model output 850 mb relative humidity.

Also given are the line of regression, fitted by least squares, and the lines of scatter. This figure shows the expected negative correlation between ΔN and RH. The equation for the line of regression is

$$\Delta N = -0.317 \text{ RH} + 24.856$$

A correlation coefficient, $r_{\Delta N \cdot RH}$, of -0.68 indicates a strong relationship between ΔN and RH. The probability of this coefficient originating from uncorrelated populations is less than 1% since the absolute value of $r_{\Delta N \cdot RH}$ is much greater than the absolute value of 2.6 σ_r where

$$\sigma_r = 0.1690$$

The scatter of ΔN about the line of regression is 2.36. The relationship between ΔN and RH accounts for 46.2% of the variance in ΔN.

The results of the regression analysis appear to be consistent with the classical theory of Rayleigh convection in the atmospheric boundary layer. Together, the two regression relationships provide a plausible description of the observed cloud behavior. The equation for γ shows that clouds begin to develop if γ = 7.9°C/km and that N increases as γ decreases. The relationship for RH shows that cloud development is enhanced if RH is greater than 78.4%. This value is close to the widely used value of 80% for cloud formation.

3. Probability Analyses

Cumulative frequency distributions of N are shown in Figures 17-18. The first figure, using a class interval of N=1, reflects the low kurtosis often typical of cloud fre-

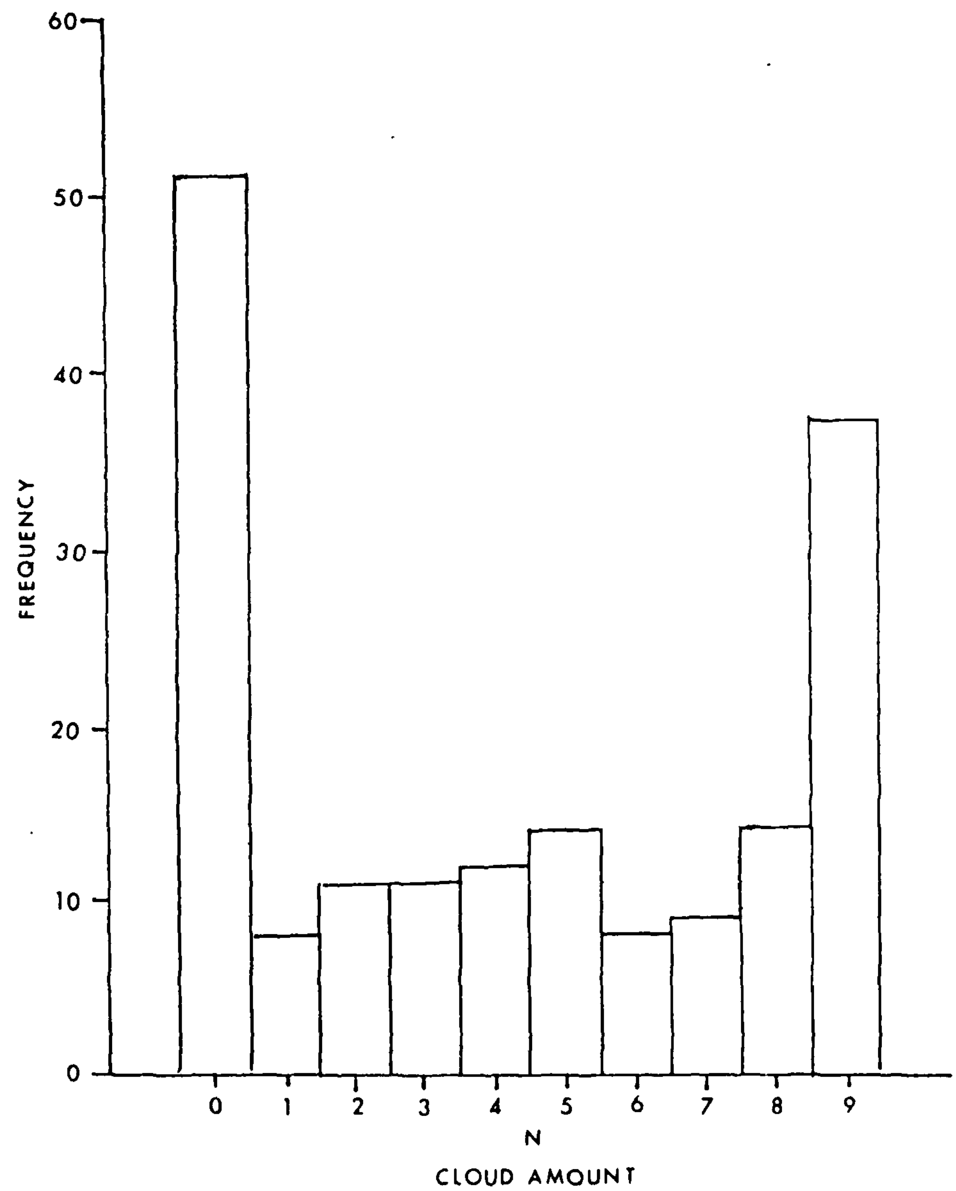

Figure 17. Cumulative frequency distribution of N for class interval of N=1.

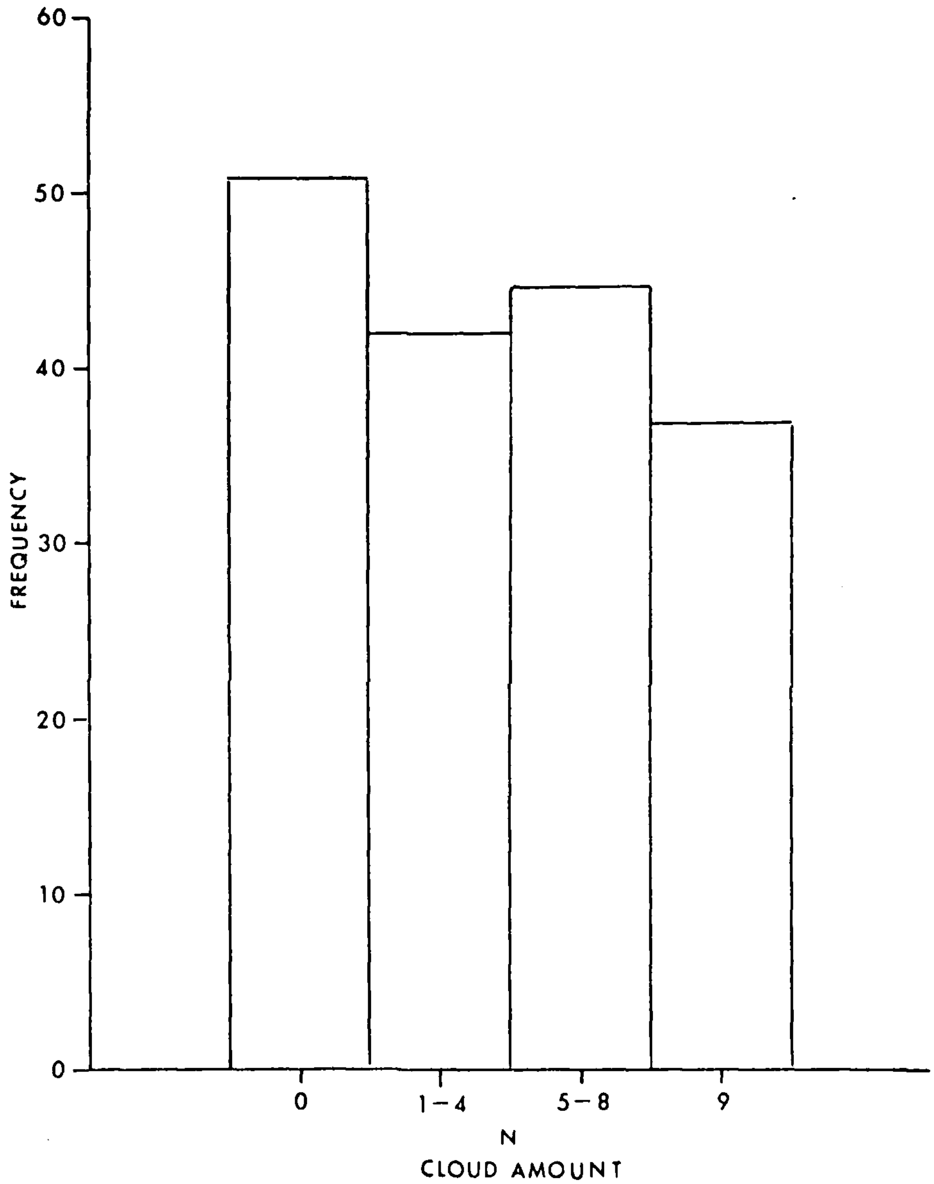

Figure 18. Cumulative frequency distribution of N for four class intervals.

quency distributions (Panofsky and Brier, 1968). Thus, either none or all of the area is more likely to be cloud covered than for any of the intermediate intervals to occur alone. However, it also shows that some cloudiness is much more probable than no cloudiness. If the intermediate intervals are combined to form just two classes between 0 and 9, the low kurtosis is no longer evident, as shown in Figure 18.

Figure 19 gives the frequency distribution of γ at 0000Z and 1200Z on days when the test area was not obscured by middle or high clouds. It is evident from this distribution and from the regression equation for γ that the atmospheric environment favors stratocumulus on most days.

Table 3 and Figure 20 present the distribution of γ when N=9. The bimodality may suggest two preferred atmospheric modes during cold air outbreaks. The ogive in Figure 21 gives a median value of 14.0°C/km for γ in cases where N=9. The cumulative probabilities of N=9 for a certain γ are given in Table 4 while Figure 22 shows the corresponding cumulative probability histogram.

Given the occurrence of N=9, one might wonder about the probability of N=9 at the end of the next 12 or 24 hours. Table 5a shows the frequency distribution of N=9 at 12 and 24 hours following one occurrence of N=9. The probability of N=9 at the end of 12 hours is 77.8% and at the end of 24 hours is 72.7%. Also of interest is the probability of N=9 at the end of the next 12 and 24 hours if N has been 9 for 12 hours (Table 5.b) and for 24 hours

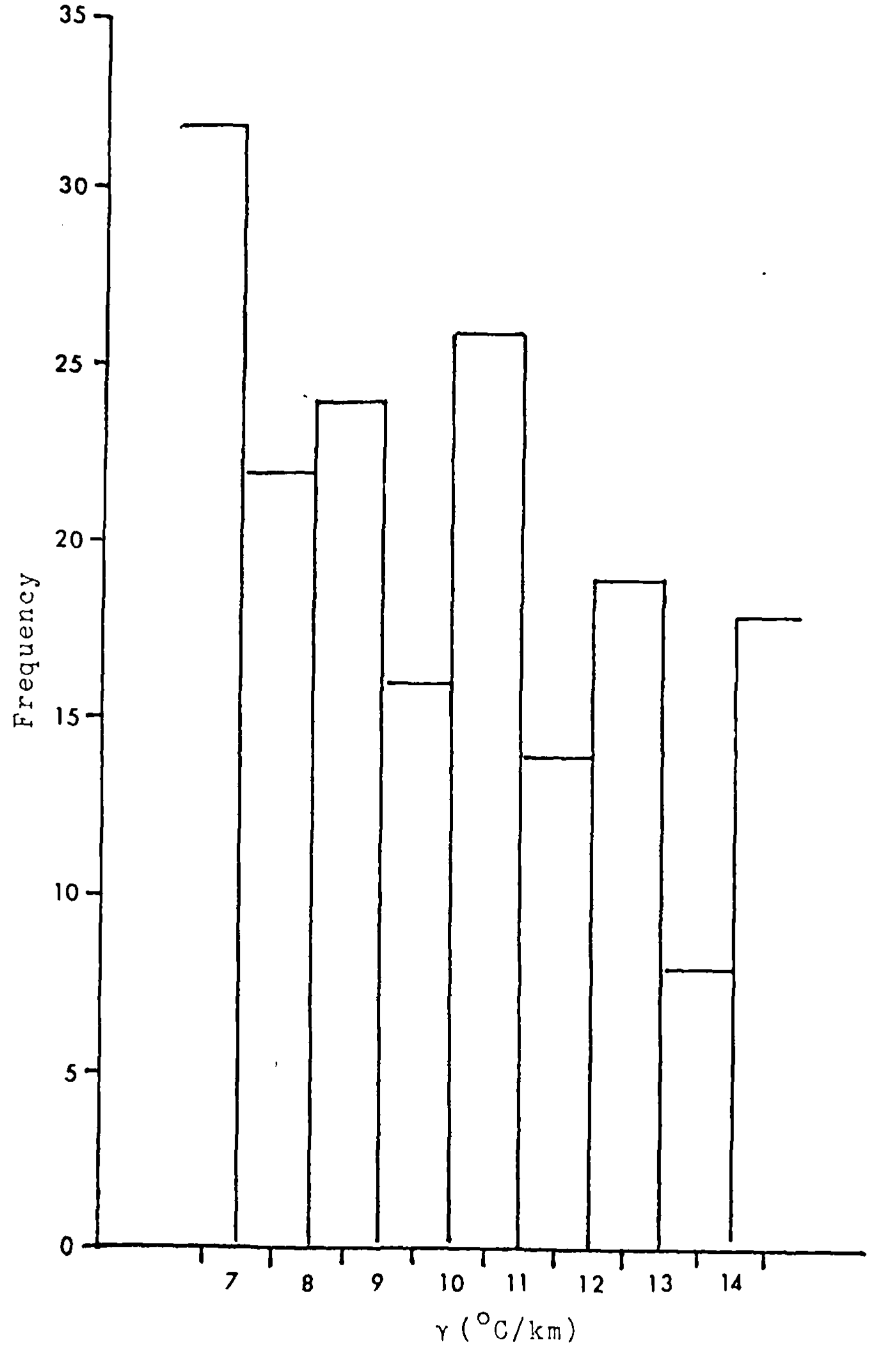

Figure 19. Cumulative frequency distribution of γ on days when the test area is not obscured by middle or high clouds.

Table 3. Cumulative frequency distribution of N=9.

γ (°C/km)	f	% of Total	CF	CF%
$\leq$ 8.9	0	0.0	0	0.0
9.0-9.9	2	5.6	2	5.6
10.0-10.9	3	8.3	5	13.9
11.0-11.9	2	5.6	7	19.5
12.0-12.9	8	22.0	15	41.7
13.0-13.9	3	8.3	18	50.0
14.0-14.9	4	11.1	22	61.1
15.0-15.9	4	11.1	26	72.2
$\geq$ 16.0	10	27.8	36	100.0

Table 4. Cumulative probability of N=9 as a function of γ.

γ (°C/km)	f_γ	CF_γ	f_9	CF_9	CP in %
< 9.0	78	179	0	0	0.0
9.0-9.9	16	101	2	2	2.0
10.0-10.9	26	85	3	5	5.9
11.0-11.9	14	59	2	7	11.9
12.0-12.9	19	45	8	15	33.3
13.0-13.9	8	26	3	18	69.2
$\geq$ 14.0	18	18	18	36	100.0

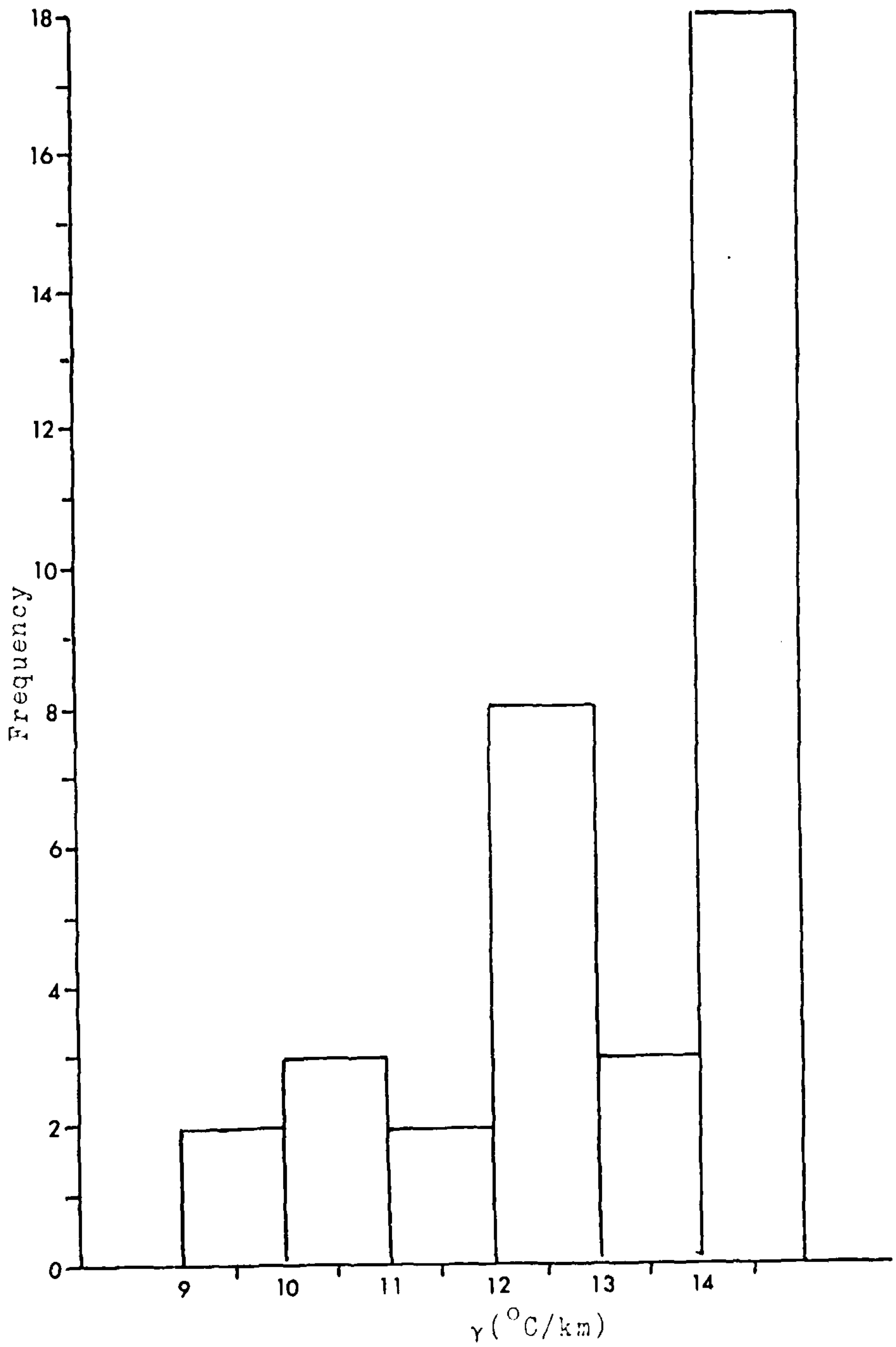

Figure 20. Cumulative frequency distribution of γ when N=9.

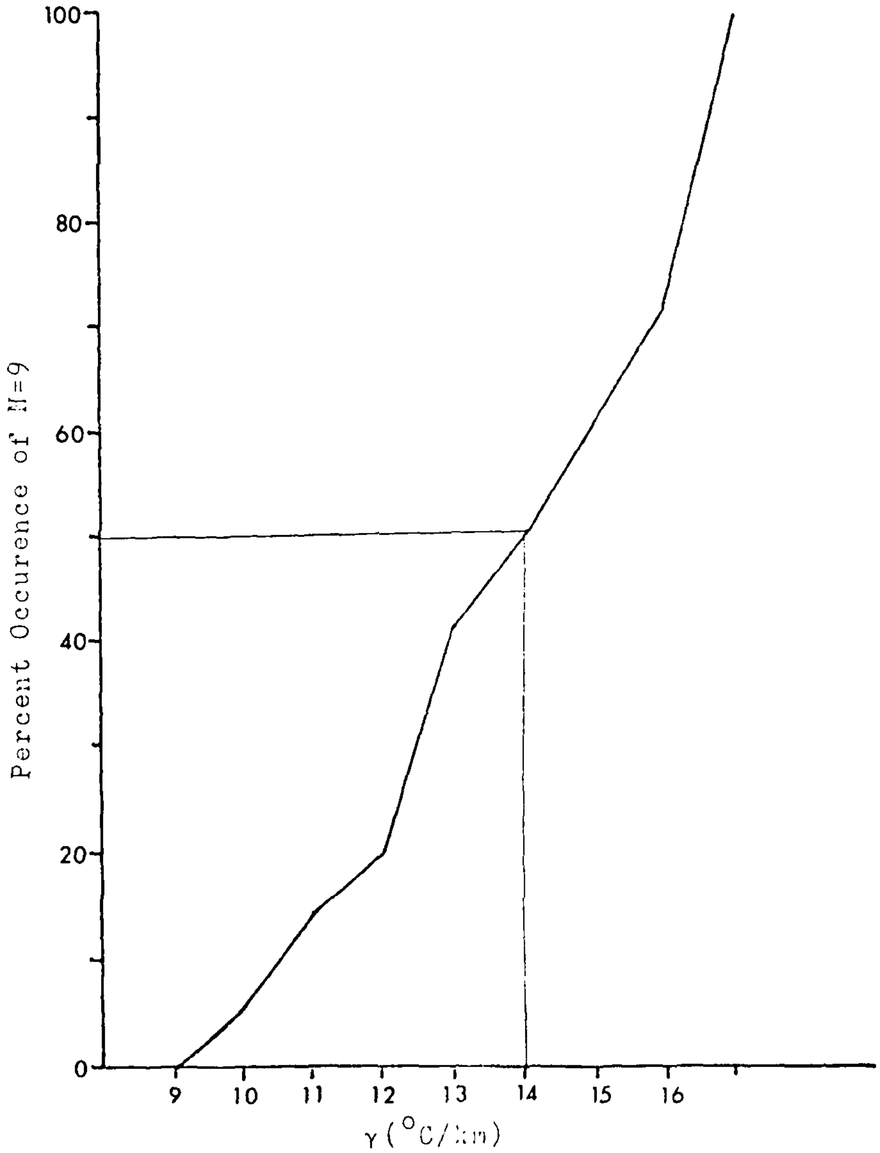

Figure 21. Ogive for median value of γ when M=9.

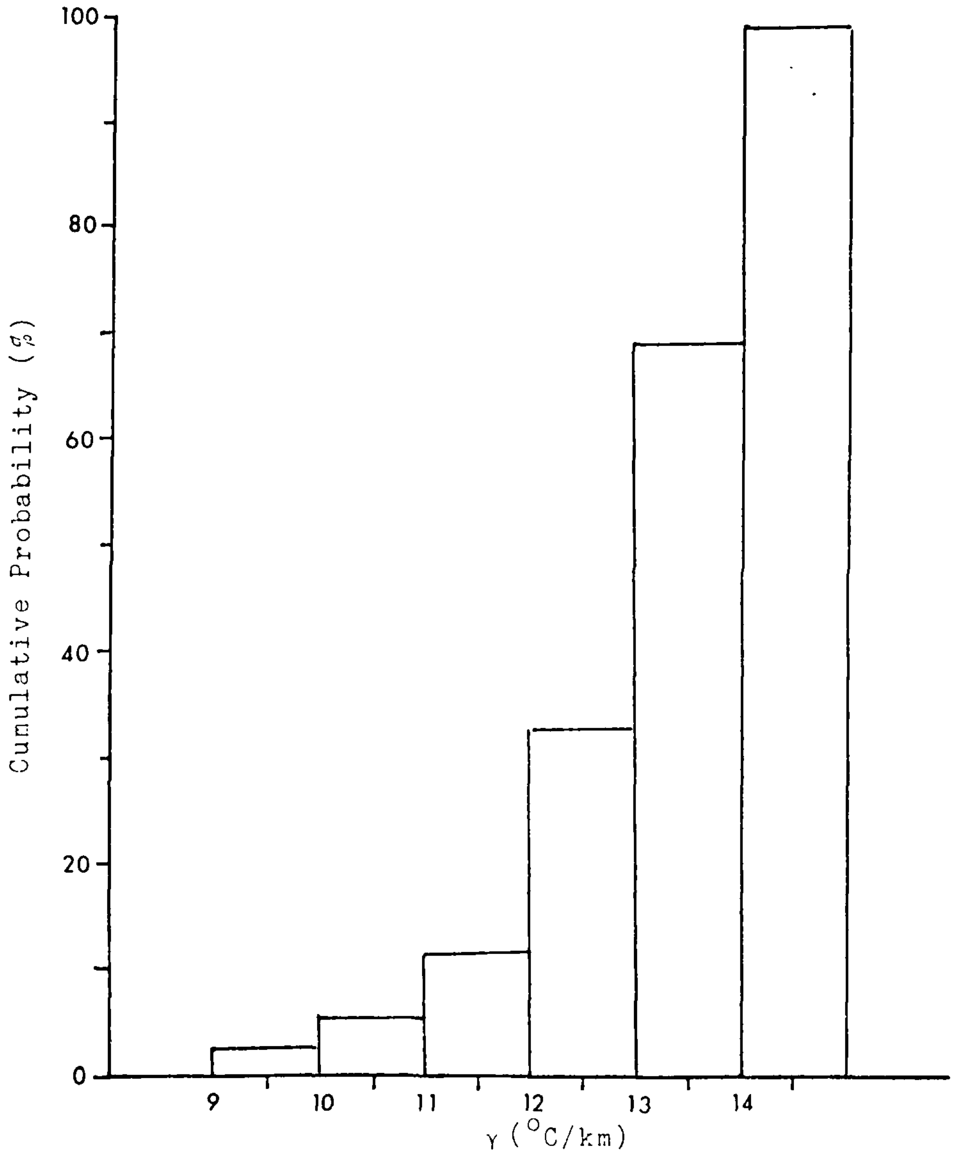

Figure 22. Cumulative probability histogram of N=9 as a function of γ.

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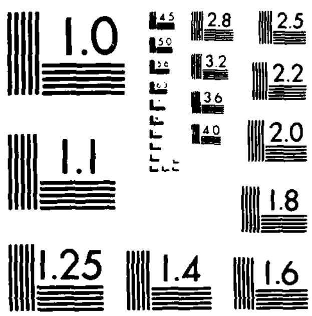

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

(Table 5.c). Table 5.d shows the most probable category of N for the first observation following the end of N=9.

The residuals are stratified into cases where ΔN is less than 0 or greater than 0, as shown in Tables 6.a-6.b and Figures 23-24. The cumulative probability histogram for cases having ΔN greater than 0 is given in Figure 23. The histogram for cases of ΔN less than 0 is given in Figure 24. These results show that the probability of the equation for γ overpredicting N increases as the model output RH decreases. Conversely, the probability of the equation for γ underpredicting N increases as the model output RH increases.

4. Outbreak Histories

Histories for individual outbreaks of cold-air stratocumulus during the period are shown in Appendix E. There is no preferred pattern in terms of length as periods as short as 5 days or as long as 16 days were observed. However, there is a tendency for the maximum cloud activity to occur toward the beginning of each outbreak as indicated by positive skewness in most cases.

The synoptic pattern in most cases showed the most vigorous cloud activity coincided with a surge of cold air advancing ahead of a large, intense anticyclone originating in the Baikal region of Siberia. Some cases showed bubble high development on the leading edge of the main high. As this bubble high split away from the main high, a trough developed between the two high pressure centers. The changes

Table 5.a. Probability of N=9 at the end of 12 and 24 hours if N is currently 9.

Time	f_0	f_{12}	f_{24}	P
12 hours	9	7	-	77.8%
24 hours	11	-	8	72.7%

Table 5.b. Probability of N=9 at the end of 12 and 24 hours if N has been 9 for 12 hours.

Time	f_0	f_{12}	f_{24}	P
12 hours	9	6	-	66.7%
24 hours	8	-	4	50.0%

Table 5.c. Probability of N=9 at the end of 12 and 24 hours if N has been 9 for 24 hours.

Time	f_0	f_{12}	f_{24}	P
12 hours	9	4	-	44.4%
24 hours	9	-	3	33.3%

Table 5.d. Most probable category for N for first observation following N=9 (based on 12 cases).

Category	Frequency	Probability
$N = 0$	0	0.0%
$0 < N \leq 3$	1	8.3%
$3 < N \leq 6$	4	33.3%
$6 < N < 9$	7	58.3%

Table 6.a. Probability of $\Delta N > 0$ as a function of model output 850 mb relative humidity (RH).

RH	f	CF	CF%	CP%
< 70.0	8	16	100.0	100.0
70.0-74.9	4	8	50.0	50.0
75.0-79.9	4	4	25.0	25.0
> 80.0	0	0	0.0	0.0

Table 6.b. Probability of $\Delta N < 0$ as a function of model output 850 mb relative humidity (RH).

RH	f	CF	CF%	CP%
< 70.0	0	0	0.0	0.0
70.0-74.9	3	3	14.3	14.3
75.0-79.9	6	9	42.9	42.9
> 80.0	12	21	100.0	100.0

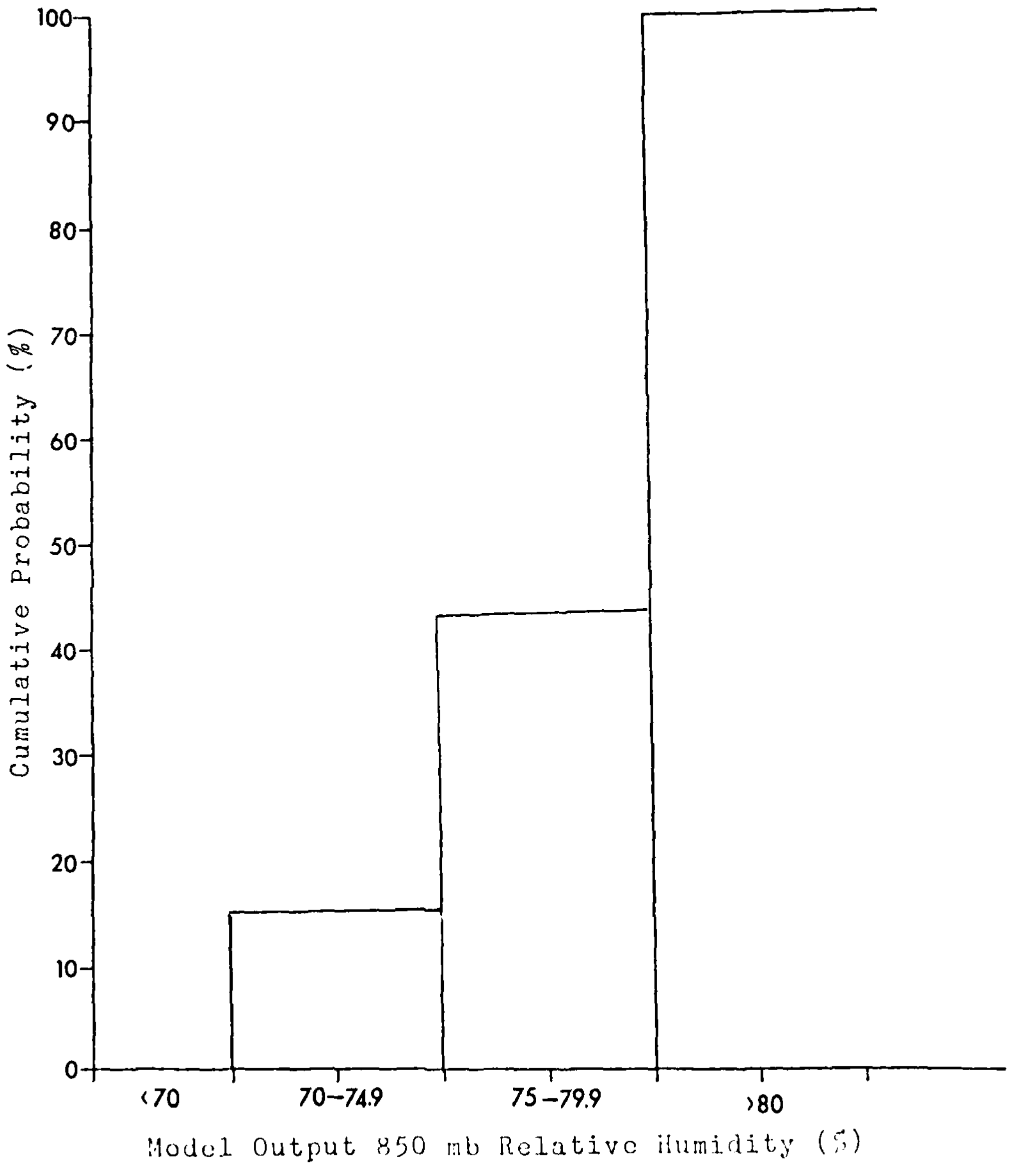

Figure 23. Cumulative probability histogram for $\Delta N<0$ as a function of model output 850 mb relative humidity.

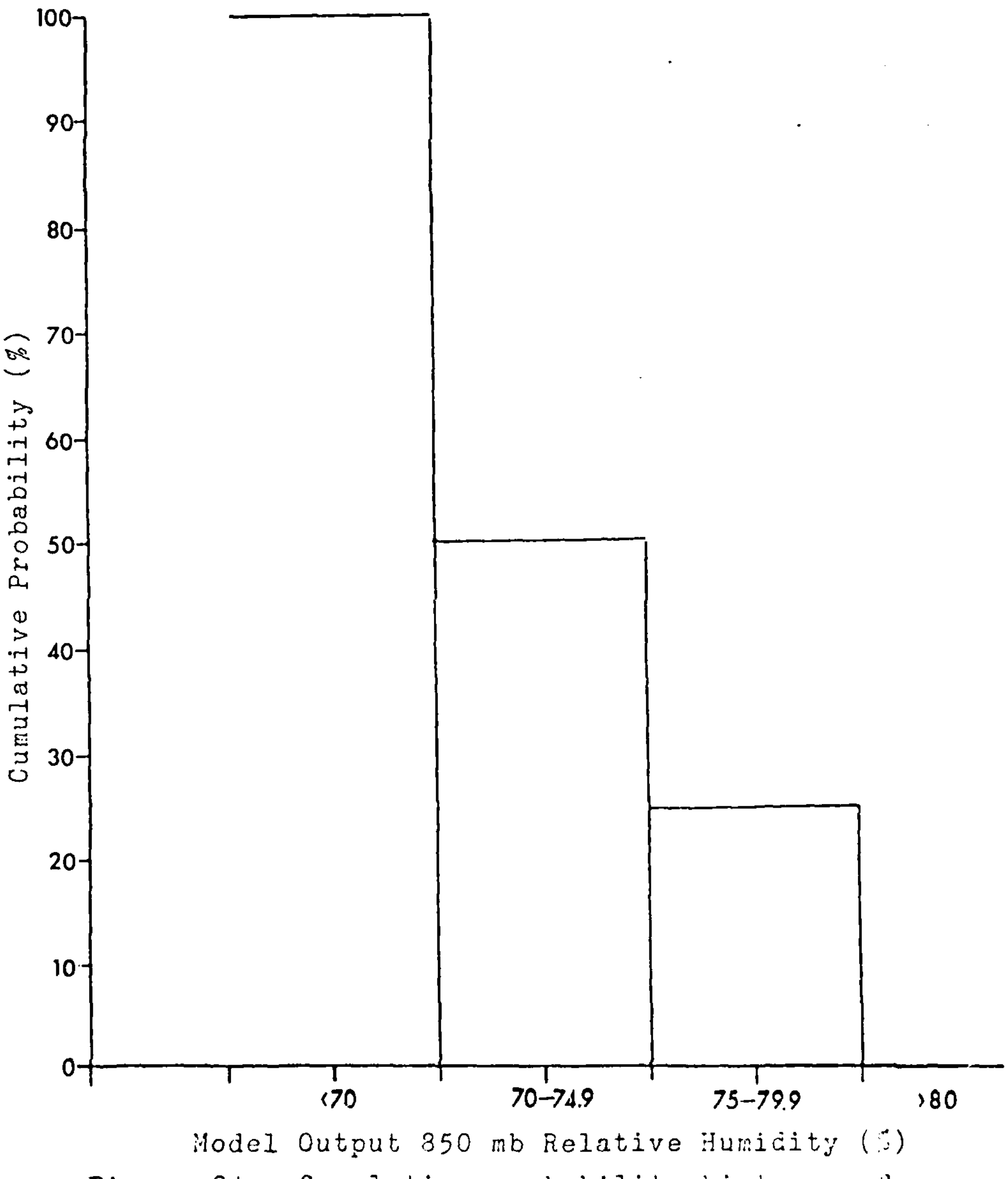

Figure 24. Cumulative probability histogram for $\Delta N > 0$ as a function of model output 850 mb relative humidity.

in wind direction associated with this trough seem to determine which coastal areas of South Korea will be affected by cold-air stratocumulus.

Although anticyclones are the dominant feature in most cases, two other patterns also appear. One of these involves the development of clouds ahead of a weak surface low moving across the Yellow Sea. The other shows cellular convection on the west side of a warm surface high located over the East China Sea. In the latter case, the clouds have the appearance of closed cell stratocumulus (Anderson et al., 1969) and look much like the clouds frequently observed in summer to the west of the continents.

CHAPTER 5

RESULTS

A. METHOD OF TESTING

One of the objectives of this research is to evaluate the statistical-dynamical model for short-range forecasts of cold air stratocumulus over the Yellow Sea. The model is tested for forecasts valid at the end of 12, 18, and 24 hours. Forty forecasts are made for each time period and are verified with respect to a 0-class error. The model skill is determined with respect to persistence, climatology, and chance.

Forecasts of cloud amount are grouped into five classes: $N=0$, $0<N\leq 3$, $3<N\leq 6$, $6<N<9$, and $N=9$. The three middle classes are to be interpreted as light, moderate, and extensive cloud coverage, respectively. Contingency tables are constructed for each time period. The skill score is given by (Panofsky and Brier, 1968)

$$S = \frac{R - E}{T - E}$$

where R is the number of correct model forecasts, T is the total number of forecasts, and E is the number of correct forecasts based on some control such as persistence, climatology, or chance. For the model to show skill, S must be greater than 0.

The verification can also be expressed in terms of the root-mean-square-error (RMSE), given by

$$\text{RMSE} = \left[\frac{\Sigma (F_i - O_i)^2}{n} \right]^{1/2}$$

where n is the total number of forecasts, F_i is the i-th forecast, and O_i is the corresponding observation.

B. MODEL INPUT

Model input is obtained from the surface and 850 mb charts and from the sea surface temperature climatology charts (Appendix B). Trajectories are forecast from the 850 mb geostrophic winds and height field. A listing of the computer program KORANL and a description of the model input parameters are given in Appendix F. Input and forecasts from KORANL are listed in Appendix G.

C. VERIFICATION OF 12-HOUR FORECASTS

Table 7 is the 12-hour cloud forecast results where N_m is the cloud amount forecast by the model, N_o is the observed cloud amount, N_p is the persistence forecast, and N_c cloud forecast based on climatology. The climatology forecast assumes $3<N\leq 6$ except in cases following one occurrence of N=9. After one occurrence of N=9, climatology forecasts another N=9, followed by $6<N<9$, and returns to $3<N\leq 6$ on the third forecast. The above scheme for climatology is based on the outbreak histories and probability studies of Chapter 4.

Table 7. Verification of 12-hour forecasts.

Valid Time	N_o	N_m	N_p	N_c
17 Nov 81/0000Z	9.0	9.0	9.0	4.5
21 Nov 81/0000Z	3.0	5.6	2.0	4.5
28 Nov 81/0000Z	7.5	9.0	8.0	4.5
21 Nov 81/1200Z	0.0	1.5	5.5	4.5
2 Dec 81/0000Z	8.0	9.0	9.0	7.5
5 Dec 81/0000Z	5.0	7.2	7.5	4.5
9 Dec 81/0000Z	1.0	2.8	4.0	4.5
10 Dec 81/0000Z	5.5	5.8	2.5	4.5
11 Dec 81/0000Z	5.0	5.2	4.0	4.5
17 Dec 81/0000Z	3.0	2.6	3.5	4.5
20 Dec 81/0000Z	6.5	6.9	9.0	7.5
23 Dec 81/0000Z	5.5	5.6	4.0	4.5
24 Dec 81/0000Z	0.5	1.0	4.0	4.5
26 Dec 81/0000Z	1.0	0.0	2.0	4.5
31 Dec 81/0000Z	7.0	5.6	8.0	7.0
9 Dec 81/1200Z	2.5	1.3	1.0	4.5
13 Dec 81/1200Z	9.0	9.0	7.5	4.5
14 Dec 81/1200Z	9.0	9.0	9.0	9.0
15 Dec 81/1200Z	7.5	6.9	7.0	4.5
19 Dec 81/1200Z	9.0	9.0	9.0	9.0
20 Dec 81/1200Z	3.5	1.5	6.5	4.5
23 Dec 81/1200Z	4.0	7.4	5.5	4.5
29 Dec 81/1200Z	7.5	7.5	9.0	4.5
31 Dec 81/1200Z	8.0	8.0	7.0	4.5
10 Jan 82/0000Z	0.0	0.0	0.0	4.5
11 Jan 82/0000Z	0.0	0.0	0.0	4.5
14 Jan 82/0000Z	5.0	6.4	9.0	9.0
20 Jan 82/0000Z	4.0	3.7	7.0	4.5
21 Jan 82/0000Z	0.0	0.0	2.0	4.5
9 Jan 82/1200Z	0.0	0.0	2.5	4.5
1 Feb 82/0000Z	2.5	5.1	6.0	4.5
2 Feb 82/0000Z	5.5	5.1	5.5	4.5

Table 7 (cont.)

Valid Time	N_o	N_m	N_p	N_c
5 Feb 82/0000Z	9.0	9.0	4.5	4.5
6 Feb 82/0000Z	9.0	9.0	7.5	4.5
7 Feb 82/0000Z	8.0	9.0	9.0	4.5
15 Feb 82/0000Z	1.5	0.0	1.5	4.5
15 Feb 82/1200Z	0.0	0.0	1.5	4.5
24 Feb 82/1200Z	0.0	0.0	0.0	4.5
26 Feb 82/1200Z	0.0	0.0	0.0	4.5
8 Feb 82/0000Z	8.0	9.0	9.0	4.5

Table 8.a is the contingency table for 12-hour model forecasts. The diagonal of 0-class errors the model to be correct in 27 of 40 cases for 67.5% accuracy. Persistence is correct in 19 of 40 cases for 47.5% accuracy. The model skill compared to persistence is 38.1%.

The expected number of correct forecasts from chance is computed from the contingency table by using the formula (Panofsky and Brier, 1968)

$$E_r = \frac{\Sigma \; R_i \; C_i}{T}$$

where R_i is the total of the i-th row, C_i is the total for the i-th column and T is the grand total. From the table one would expect forecasts based on chance to be correct in 8 cases. The model skill compared to chance is 59.4%. Climatology is correct in 13 cases; the model skill compared to climatology is 51.8%. Table 8.b summarizes the model skill with respect to each control.

The RMSE of the model forecasts is 1.2 while that of persistence is 2.1. The model thus gives a 43.1% reduction in error over persistence.

Since this test takes credit only for the 0-class errors, it is one of the most stringent that can be applied. Some verification schemes allow for 1-category errors. If a 1-category error is used for the 12-hour model forecasts, the model accuracy is 100% compared to 92.5% for persistence. The skill score then becomes 100% with respect to all three controls.

Table 8.a. Contingency table for 12-hour model forecasts.

Observed	Model Forecast N=0	$0<N\leq 3$	$3<N\leq 6$	$6<N<9$	N=9	Total
N=0	7	0	0	0	0	7
$0<N\leq 3$	3	4	1	0	0	8
$3<N\leq 6$	0	2	5	3	0	10
$6<N<9$	0	0	1	5	3	9
N=9	0	0	0	0	6	6
TOTAL	10	6	7	8	9	40

Table 8.b. Skill of 12-hour model forecasts with respect to persistence, climatology, and chance (based on 40 forecasts).

Control	*No. of correct forecasts based on control	*No. of correct forecasts based on model	Skill %
Persistence	19	27	38.1
Climatology	13	27	51.8
Chance	8	27	59.4

*Verification based on 0-category error.

D. VERIFICATION OF 18-HOUR FORECASTS

The 18-hour model forecasts cover the period from September through November 1982. Because NOAA-6 was no longer transmitting usable data, only pictures from NOAA-7 were available for verification and for making persistence forecasts. Thus, the 18-hour model forecast is compared to 12-hour persistence and climatology forecasts.

Table 9 is the 18-hour forecast results while Table 10.a is the corresponding contingency table. For an 0-class error, the model forecasts verify in 25 of 40 cases for 62.5% accuracy. Persistence (based on a 12-hour period) is correct 17 times for 47.5% accuracy. The model skill with respect to persistence is 31.8%.

From the contingency table, one would expect chance to be correct in 8 cases. Thus, the model skill compared to chance is 53.1%. Climatology is correct in 7 cases. The model skill compared to climatology is 54.6%. Table 10.b summarizes the model skill with respect to each control.

The model forecast RMSE is 1.3 compared to 2.4 for persistence, giving a reduction in error of 44.6%. The model accuracy if one allows for 1-category errors in verification is 100%.

F. VERIFICATION OF 24-HOUR FORECASTS

The 24-hour forecasts use data from the period of November 1981 through February 1982. Both NOAA-6 and NOAA-7 are available.

Table 9. Verification of 18-hour forecasts.

Valid Time	N_o	N_m	N_p	N_c
20 Sep 82/1800Z	5.0	4.2	6.0	4.5
23 Sep 82/0600Z	0.0	0.0	0.0	4.5
26 Sep 82/1800Z	8.0	9.0	9.0	9.0
27 Sep 82/0600Z	5.0	5.4	8.0	7.5
27 Sep 82/1800Z	8.0	5.0	5.0	4.5
15 Oct 82/1800Z	2.5	4.8	6.0	4.5
16 Oct 82/0600Z	1.0	2.5	2.5	4.5
17 Oct 82/0600Z	7.0	4.1	8.0	4.5
17 Oct 82/1800Z	3.0	3.0	7.0	4.5
18 Oct 82/0600Z	3.0	1.9	3.0	4.5
19 Oct 82/0600Z	8.0	4.0	8.0	4.5
19 Oct 82/1800Z	6.5	5.5	8.0	4.5
20 Oct 82/0600Z	2.0	2.0	6.0	4.5
23 Oct 82/0600Z	8.0	9.0	9.0	9.0
23 Oct 82/1800Z	9.0	9.0	8.0	7.5
24 Oct 82/1800Z	6.5	6.8	9.0	7.5
25 Oct 82/0600Z	4.0	4.6	6.5	7.5
25 Oct 82/1800Z	4.0	3.4	4.0	4.5
5 Nov 82/1800Z	4.5	3.2	4.5	4.5
9 Nov 82/1800Z	9.0	9.0	9.0	9.0
10 Nov 82/0600Z	9.0	9.0	9.0	7.5
10 Nov 82/1800Z	9.0	9.0	9.0	4.5
11 Nov 82/0600Z	8.0	9.0	9.0	4.5
17 Nov 82/1800Z	9.0	9.0	3.0	4.5
19 Nov 82/0600Z	2.0	3.1	9.0	9.0
19 Nov 82/1800Z	5.0	6.2	2.0	4.5
22 Nov 82/0600Z	6.5	4.8	9.0	9.0
22 Nov 82/1800Z	9.0	9.0	6.0	4.5
24 Nov 82/0600Z	9.0	9.0	6.0	4.5
29 Nov 82/1800Z	7.0	7.3	9.0	4.5
30 Nov 82/0600Z	6.5	5.3	7.0	4.5

Table 9 (cont.)

Valid Time	N_o	N_m	N_p	N_c
12 Oct 82/1800Z	0.0	0.0	0.0	4.5
18 Oct 82/1800Z	3.0	0.0	0.0	4.5
5 Oct 82/1800Z	2.0	0.0	0.0	4.5
24 Sep 82/1800Z	0.0	0.0	0.0	4.5
12 Oct 82/0600Z	0.0	0.0	3.0	4.5
23 Sep 82/1800Z	0.0	0.0	0.0	4.5
25 Sep 82/1800Z	0.0	0.0	0.0	4.5
11 Nov 82/1800Z	8.0	9.0	8.0	4.5
24 Nov 82/1800Z	9.0	9.0	9.0	9.0

Table 10.a. Contingency table for 18-hour model forecasts.

	Model Forecast					
Observed	N=0	0<N≤3	3<N≤6	6<N<9	N=9	Total
N=0	6	1	0	0	0	7
0<N≤3	1	4	2	0	0	7
3<N≤6	0	0	5	2	0	7
6<N<9	0	0	5	2	4	11
N=9	0	0	0	0	8	8
TOTAL	7	5	12	4	12	40

Table 10.b. Skill of 18-hour model forecasts with respect to persistence, climatology, and chance (based on 40 forecasts).

Control	*No. of correct forecasts based on control	*No. of correct forecasts based on model	Skill %
Persistence	18	25	31.8
Climatology	7	25	54.6
Chance	8	25	53.1

*Verification based on 0-category error.

Table 11 gives the 24-hour forecast results while Table 12.a is the corresponding contingency table. For a 0-class error, the model forecasts verify in 19 cases for 47.5% accuracy. Persistence is correct 10 times for 25.0% accuracy while climatology is correct 12 times for 30.0% accuracy. The model skill with respect to persistence is 30.0% and with respect to climatology is 25.0%. One reason that climatology performs better than persistence in this test is that more cases were chosen from this class interval $3<N\leq 6$. There are 13 cases where $3<N\leq 6$ compared to 10 in the 12-hour test and 7 in the 18-hour test. Table 12.b summarizes the model skill with respect to these controls.

According to the contingency table, one would expect chance to be correct in 7 cases. The model skill compared to chance is 36.4%.

The model forecast RMSE is 2.5 compared to 3.5 for persistence and 2.9 for climatology. The model's reduction in error is 28.6% compared to persistence and 13.8% compared to climatology.

Allowing for 1-category errors, the model has 80% accuracy compared to 75% for climatology and 65% for persistence. The model skill is 20.0% with respect to climatology and 42.8% with respect to persistence.

Table 11. Verification of 24-hour forecasts.

Valid Time	N_o	N_m	N_p	N_c
13 Nov 81/0000Z	0.5	0.0	2.0	4.5
18 Nov 81/0000Z	9.0	6.6	9.0	9.0
19 Nov 81/0000Z	8.0	7.2	9.0	4.5
28 Nov 81/0000Z	7.5	9.0	8.5	4.5
9 Nov 81/1200Z	7.5	9.0	9.0	4.5
15 Nov 81/1200Z	0.5	2.1	0.0	4.5
18 Nov 81/1200Z	5.0	2.5	8.0	4.5
26 Nov 81/1200Z	4.0	9.0	5.0	4.5
28 Nov 81/1200Z	4.0	4.4	7.5	4.5
4 Dec 81/0000Z	5.0	9.0	9.0	9.0
5 Dec 81/0000Z	5.0	4.5	7.0	4.5
6 Dec 81/0000Z	5.0	5.9	5.0	4.5
7 Dec 81/0000Z	5.0	9.0	5.0	4.5
8 Dec 81/0000Z	3.0	9.0	5.0	4.5
9 Dec 81/0000Z	1.0	2.4	3.0	4.5
10 Dec 81/0000Z	5.5	3.4	1.0	4.5
11 Dec 81/0000Z	5.0	1.6	5.5	4.5
5 Dec 81/1200Z	3.0	8.2	7.5	4.5
9 Dec 81/1200Z	2.5	2.2	4.0	4.5
15 Dec 81/1200Z	7.5	9.0	9.0	4.5
20 Dec 81/1200Z	3.5	0.0	9.0	9.0
21 Dec 81/1200Z	0.0	0.0	3.5	4.5
24 Dec 81/1200Z	0.0	0.0	4.0	4.5
29 Dec 81/1200Z	7.5	7.4	0.0	4.5
2 Jan 82/0000Z	2.0	0.0	8.0	4.5
3 Jan 82/0000Z	0.0	0.0	2.0	4.5
5 Jan 82/0000Z	4.5	1.6	0.0	4.5
9 Jan 82/0000Z	2.5	3.7	8.0	4.5
10 Jan 82/0000Z	0.0	0.0	2.5	4.5
11 Jan 82/0000Z	0.0	0.0	0.0	4.5
12 Jan 82/0000Z	9.0	9.0	0.0	4.5

Table 11 (cont.)

Valid Time	N_c	N_m	N_p	N_c
13 Jan 82/0000Z	8.0	9.0	9.0	9.0
14 Jan 82/0000Z	5.0	9.0	9.0	4.5
15 Jan 82/0000Z	9.0	9.0	5.0	4.5
20 Jan 82/0000Z	4.0	4.9	9.0	4.5
12 Jan 82/1200Z	9.0	9.0	9.0	7.5
20 Jan 82/1200Z	2.0	4.5	7.0	4.5
27 Jan 82/1200Z	9.0	9.0	9.0	4.5
7 Feb 82/0000Z	8.0	9.0	9.0	9.0
13 Feb 82/1200Z	3.0	2.6	0.0	4.5

Table 12.a. Contingency table for 24-hour model forecasts.

Observed	Model Forecast N=0	$0<N\leq 3$	$3<N\leq 6$	$6<N<9$	N=9	Total
N=0	5	0	0	0	0	5
$0<N\leq 3$	3	3	1	2	1	10
$3<N\leq 6$	1	3	5	0	4	13
$6<N<9$	0	0	0	2	5	7
N=9	0	0	0	1	4	5
TOTAL	9	6	6	5	14	40

Table 12.b. Skill of 24-hour model forecasts with respect to persistence, climatology, and chance (based on 40 forecasts).

Control	*No. of correct forecasts based on control	*No. of correct forecasts based on model	Skill %
Persistence	10	19	30.0
Climatology	12	19	25.0
Chance	7	19	36.4

*Verification based on 0-category error.

CHAPTER 6

CONCLUSIONS

The main objective of this research was to develop and test a statistical-dynamical model for forecasting cold-air stratocumulus over the Yellow Sea. Another aim was to investigate the seasonal climatology of mesoscale cellular convection during the 1981-1982 northwest winter monsoon. To these ends, the study relied heavily on satellite data in the statistical analysis.

By relating the degree of convective activity to a boundary layer stability parameter, it was possible to formulate statistical forecast equations for cloud amount over a defined area. Existing Lagrangian models for the planetary boundary layer (Lilly, 1968; Carson and Smith, 1974; Deardorff, 1976; Schubert et al., 1979; Stage, 1979; Albrecht et al., 1979; Randall, 1980; Stage and Businger, 1981) provided the conceptual framework for a much simplified two-layer Lagrangian model suitable for a microcomputer. Model output was used in the analysis of cloud amount errors based on predictions from the stability parameter. A statistical relationship between the forecast 850 mb relative humidity and the forecast errors permitted use of the residual method in forecasting cloud amounts.

It was determined that the model showed considerable forecast skill for time periods of 12, 18, and 24 hours when

compared to forecasts based on persistence, chance, and climatology. The study also showed that persistence forecasts were more successful than climatology except for a forecast period of 24 hours.

Trajectories constructed from the 850 mb analysis were used in determining the input parameters. The test results seem to favor this procedure for short-range applications of the model. However, the validity of this method depends heavily upon one's experience and analysis skills. Yet, it is still significant that this apparent disadvantage offers no strong restrictions to operational use of the model.

Perhaps the most important aspect of this study is the model's success despite its simplicity. It appears that this success was partly achieved by selecting a predictor closely related to the physics of Rayleigh convection. Another key factor was the use of a cloud level moisture variable and model output statistics in the development of the residual relationship. In both predictors other important effects are implicit. For example, the simulation includes the effects of fetch, sea surface temperature and moisture gradients, and surface fluxes of sensible and latent heat. By combining the two statistical equations with the model output, a remarkably accurate simulation of stratocumulus development emerges.

Forecast verification showed that the model performed particularly well in timing the onset and extent of major outbreaks of cold air stratocumulus. This result is signi-

ficant in evaluating the model's potential as a forecast tool.

Test results from the computer program KORANL suggest other possible applications. For example, several trajectories could be used in doing a neph-analysis of cold air stratocumulus over a broad area. The analysis could use either the area forecasts produced from the statistical equations or a point method, assuming clouds form if the 850 mb relative humidity is greater than 80%.

The model could also be applied to point forecasting of temperature and precipitation. The model includes a routine for forecasting snow. An example of a point forecast for snow in Seoul, Korea is shown in Appendix H.

The seasonal climatology indicates that most cold air stratocumulus over the Yellow Sea occurs between November and March, although data from the fall of 1982 show outbreaks in late September. It is also possible that the phenomenon may occur in early March, though not observed in this study. In most cases, the areal coverage and intensity of the clouds is proportional to the intensity of the invading cold air. Maximum a tivity occurs during great surges of cold air. Minimum activity occurs when changes in the synoptic flow disrupt the northwest monsoon.

Further study is needed to determine if the model is applicable to other areas such as the western Atlantic or the Great Lakes. The size of the test area used in this research would be too large for forecasting clouds over the

Great Lakes, which are much smaller than the Yellow Sea. However, the model should be applicable to point forecasting temperature, relative humidity, and snowfall along the shores of the Great Lakes.

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APPENDIX A

METHOD OF ESTIMATING VERTICAL VELOCITY

The technique for estimating the vertical velocity along the trajectory involves map typing. It is assumed that similar vertical velocities are associated with certain recurring synoptic patterns at the surface and 850 mb levels.

The following steps are involved in the application of this method:

1. Analysis of the surface pressure and 850 mb heights.

2. Construction of the 850 mb forecast trajectory.

3. Assigning a map type from Figures A1-A7 based on the surface and 850 mb analyses. (The fixed test point (36°N, 125°E) appears as ⊗ in these figures.)

4. Determining the position of the trajectory with respect to the areas of expected vertical motion.

Case histories from the winter of 1981-82 showed the following patterns to be the most significant:

1. Weakening surface low with approaching 850 mb short wave. Vertical velocity ahead of short wave axis is 0.5 cm/s (Figure A1).

2. Elongated trough tilting southwest to northeast at the surface and at 850 mb. Vertical velocity ahead of 850 mb trough axis is 1.0 cm/s (Figure A2).

3. Weakening closed low at both the surface and at 850 mb. Vertical velocity ahead of the 850

mb trough axis is 1.5 cm/s (Figure A3).

4. Well-developed and intensifying closed low at both the surface and at 850 mb. Vertical velocity within closed contours is 2.0 cm/s (Figure A4).

5. Bubble high at the surface and very weak short wave imbedded in the 850 mb flow. Vertical velocity is 0.25 cm/s ahead of the 850 mb short wave and between the two surface high pressure centers. Vertical velocity is -0.25 cm/s within 200 km of the surface high center (Figure A5).

6. Warm high at the surface and at 850 mb extending northward from the East China Sea. Vertical velocity is -0.5 cm/s within 300 km of the surface high center (Figure A6).

7. Cold high at the surface and at 850 mb located over western China and producing steady northwest flow over the Yellow Sea. Vertical velocity nearly 0.0 cm/s over the Yellow Sea (Figure A7).

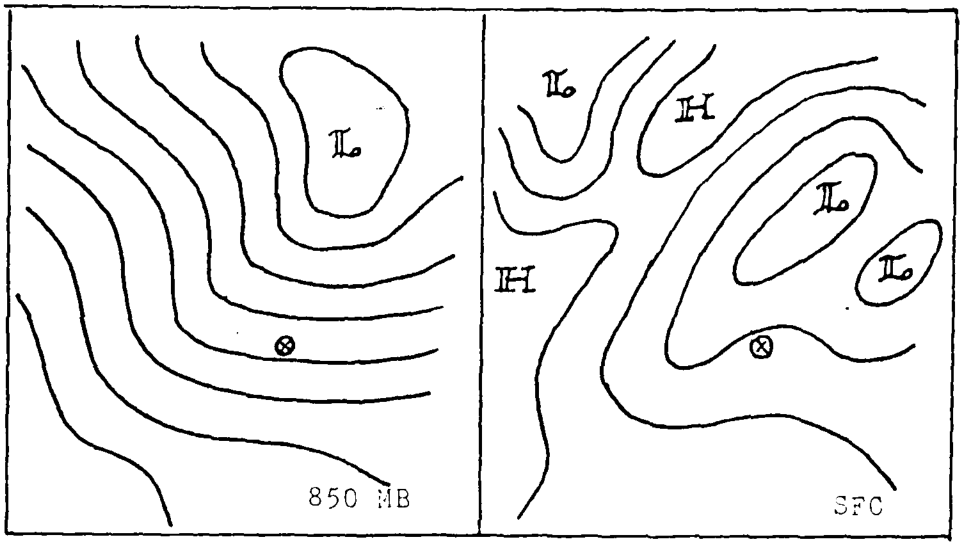

Figure A1. Weakening surface low with approaching 850 mb short wave. Vertical velocity ahead of short wave axis is 0.5 cm/s. Vertical velocity in northwest flow behind short wave is near 0.0 cm/s.

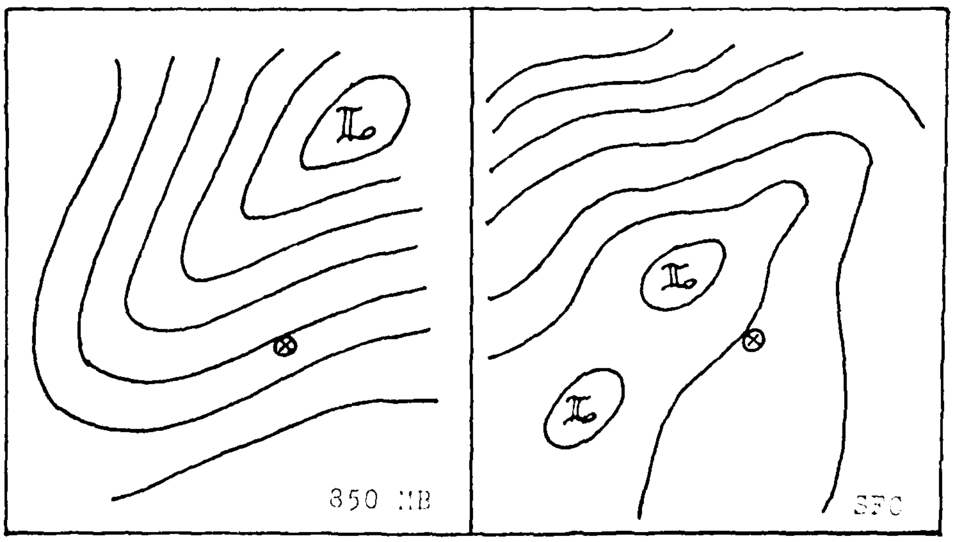

Figure A2. Elongated trough tilting southwest to northeast at the surface and at 850 mb. Vertical velocity ahead of 850 mb trough axis is 1.0 cm/s. Vertical velocity to rear of axis is 0.0 cm/s.

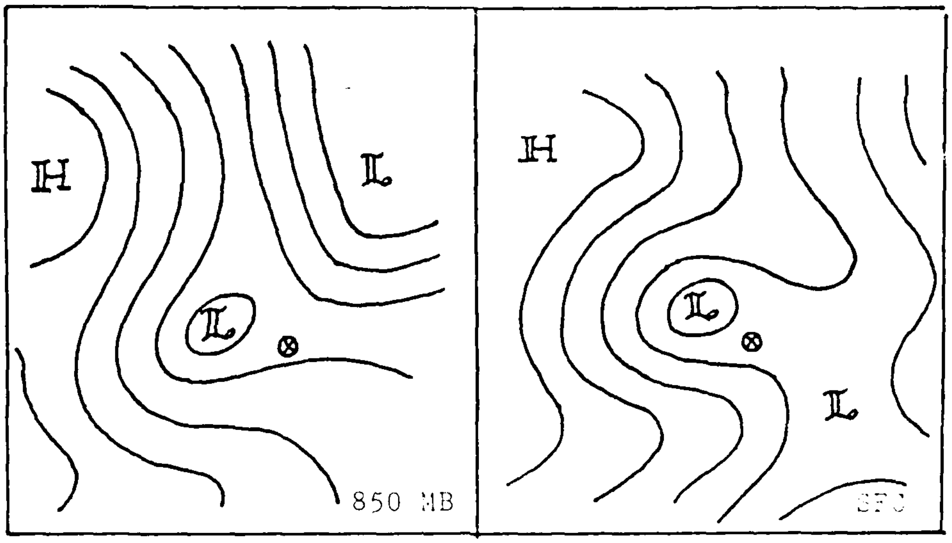

Figure A3. Weakening closed low at both the surface and at 850 mb. Vertical velocity ahead of the 850 mb trough axis is 1.5 cm/s.

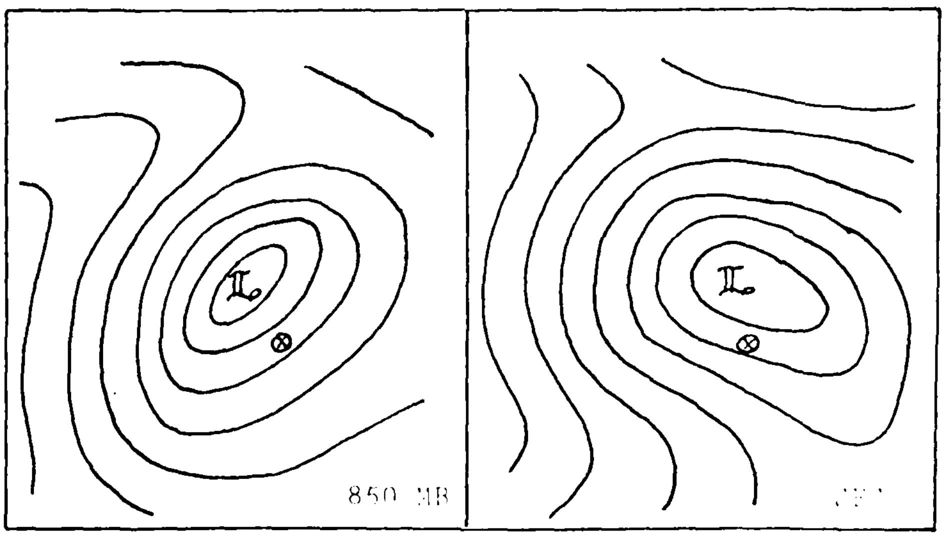

Figure A4. Well developed and intensifying closed closed low at both the surface and at 850 mb. Vertical velocity within the closed contours is 2.0 cm/s.

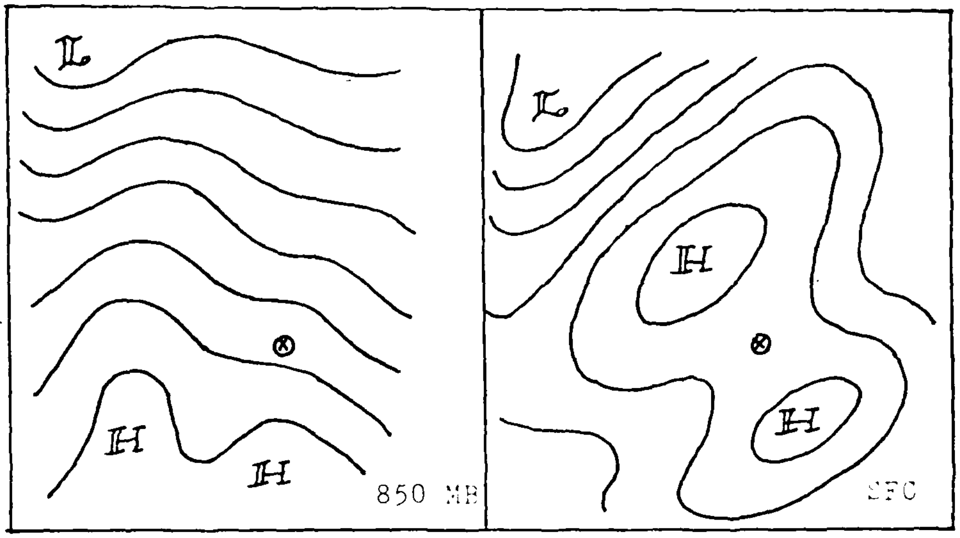

Figure A5. Bubble high at the surface and a weak short wave imbedded in the 850 mb flow. Vertical velocity is 0.25 cm/s ahead of the 850 mb short wave and between the two surface high pressure centers. Vertical velocity is -0.25 cm/s within 200 km of the surface high pressure center.

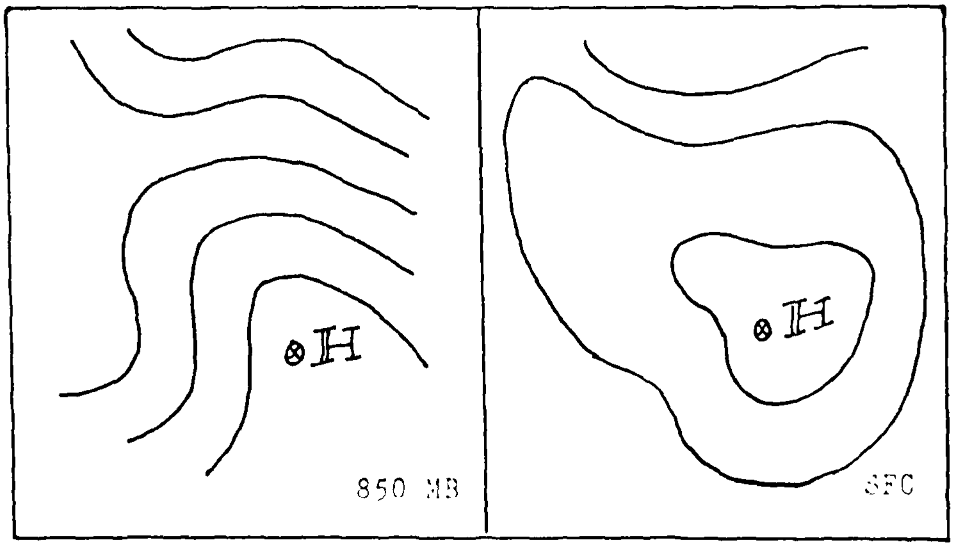

Figure A6. Warm high at the surface and at 850 mb extends northward from the East China Sea. Vertical velocity is -0.5 cm/s within 300 km of the surface high center.

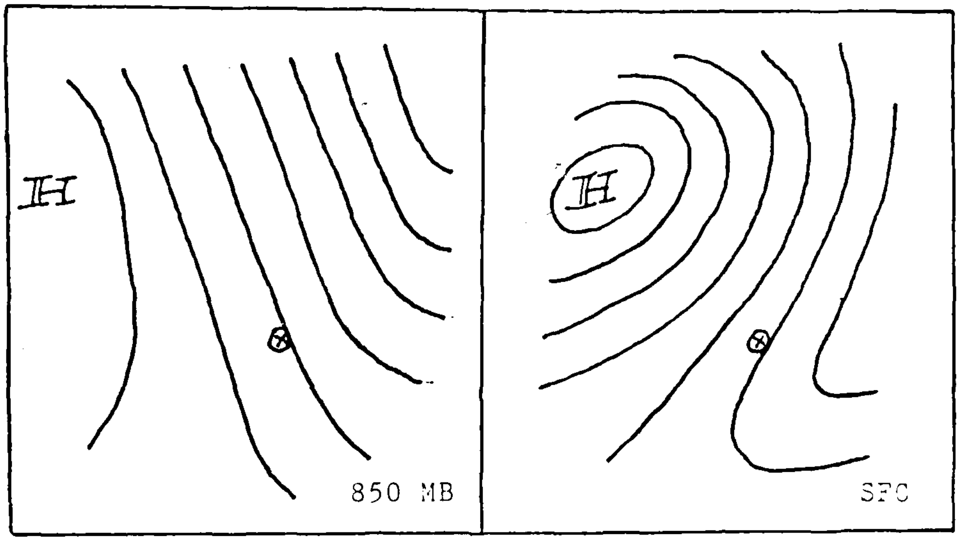

Figure A7. Cold high at the surface and at 850 mb located over western China and producing steady northwest flow over the Yellow Sea. Vertical velocity nearly 0.0 cm/s over the Yellow Sea.

APPENDIX B

SEA SURFACE TEMPERATURE CLIMATOLOGY CHARTS FOR THE YELLOW SEA

Figures B1-B7 represent the monthly mean sea surface temperature climatology for the Yellow Sea (U.S. Navy, 1977). All temperatures are in degrees Celsius.

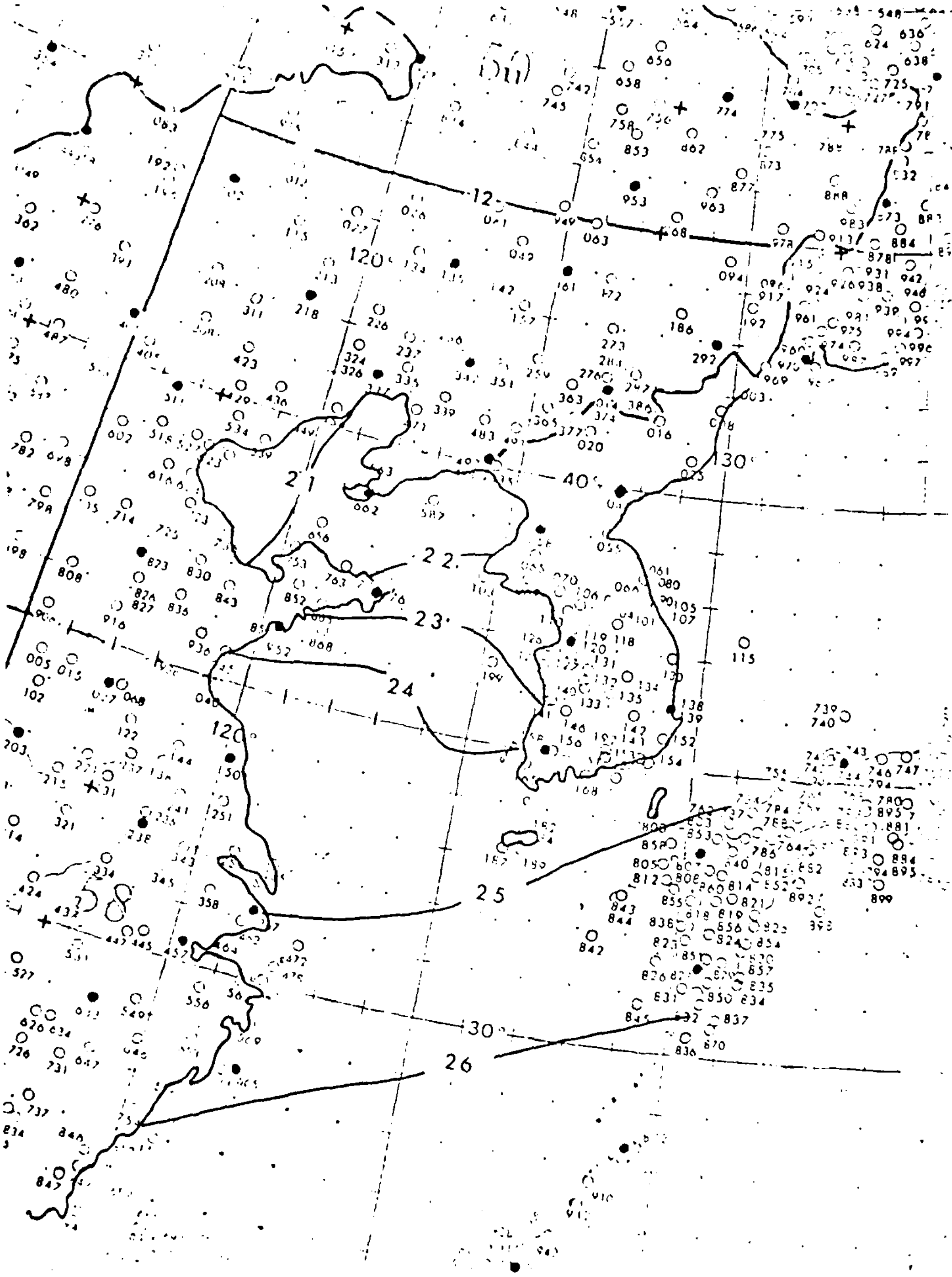

Figure B1. Mean sea surface temperature climatology ($^{\circ}C$) for September.

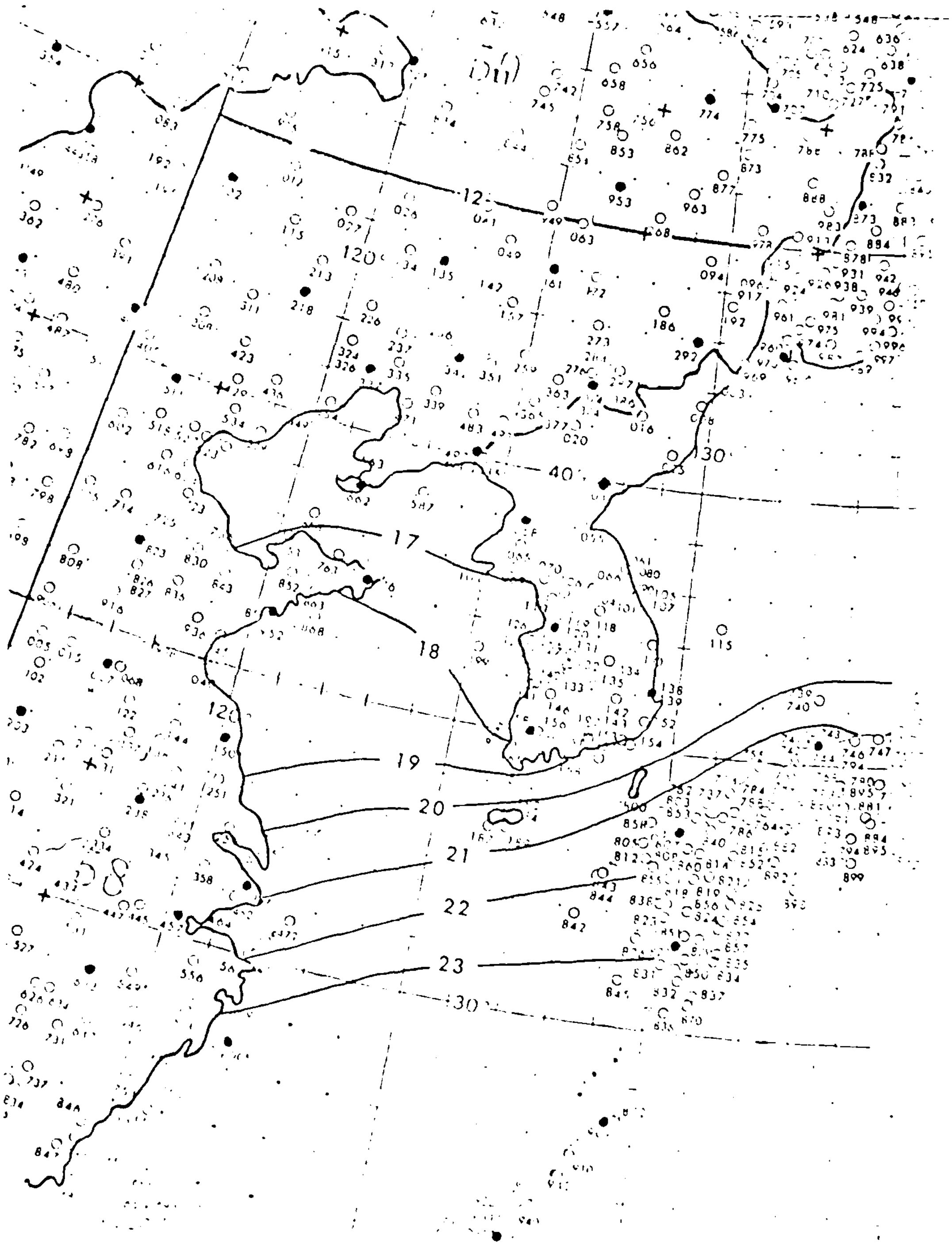

Figure B2. Mean sea surface temperature climatology (°C) for October.

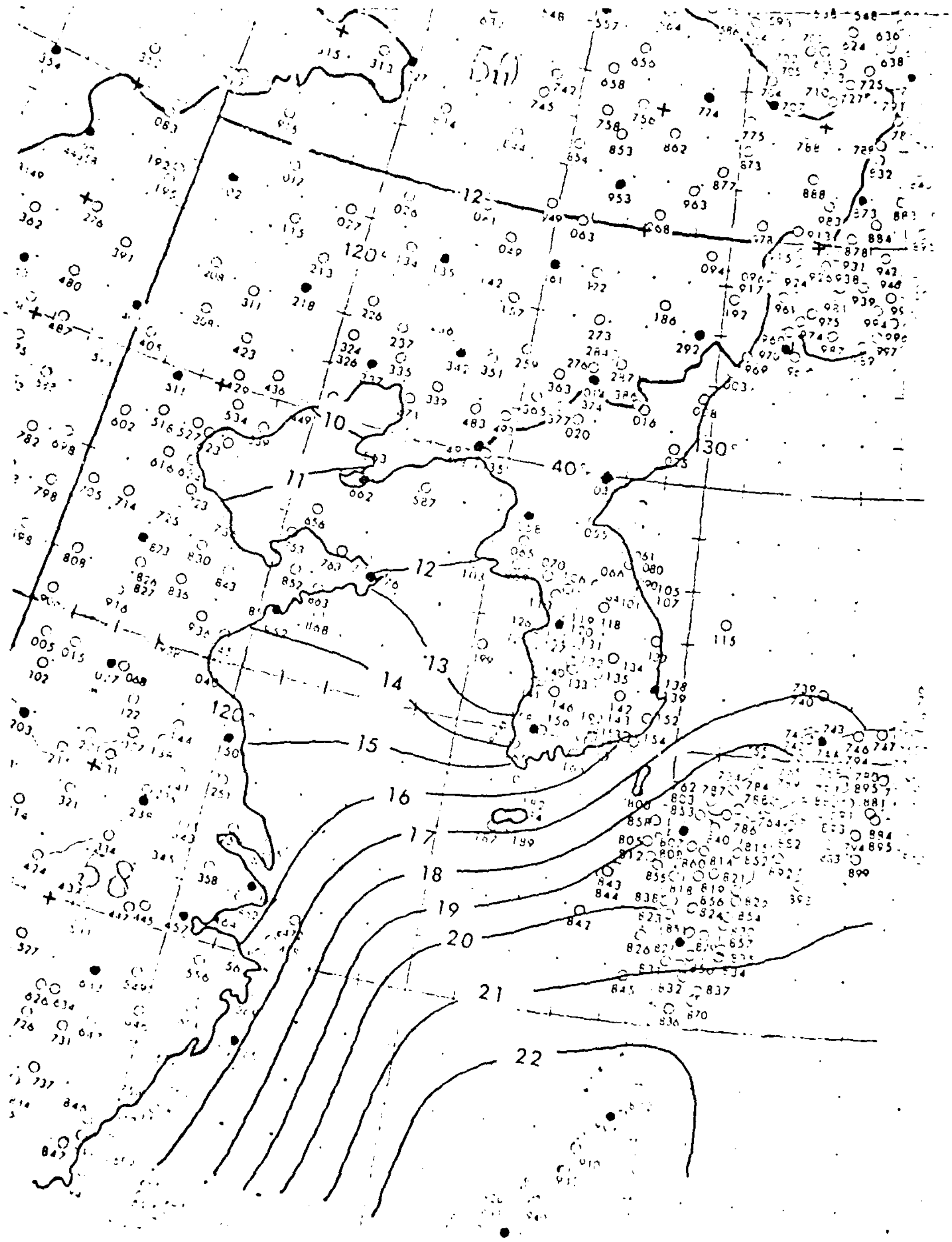

Figure B3. Mean sea surface temperature climatology (°C) for November.

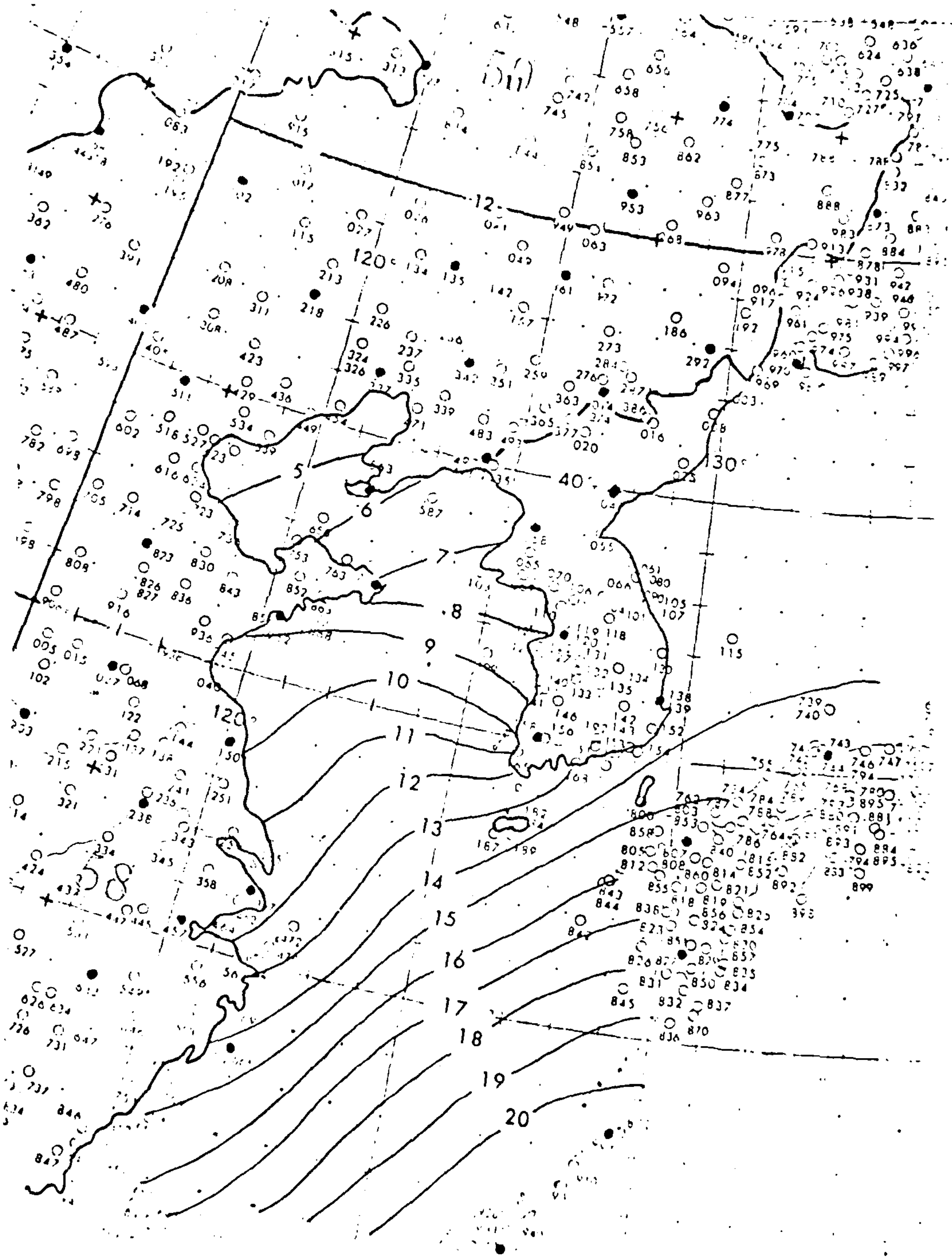

Figure B4. Mean sea surface temperature climatology ($^{\circ}C$) for December.

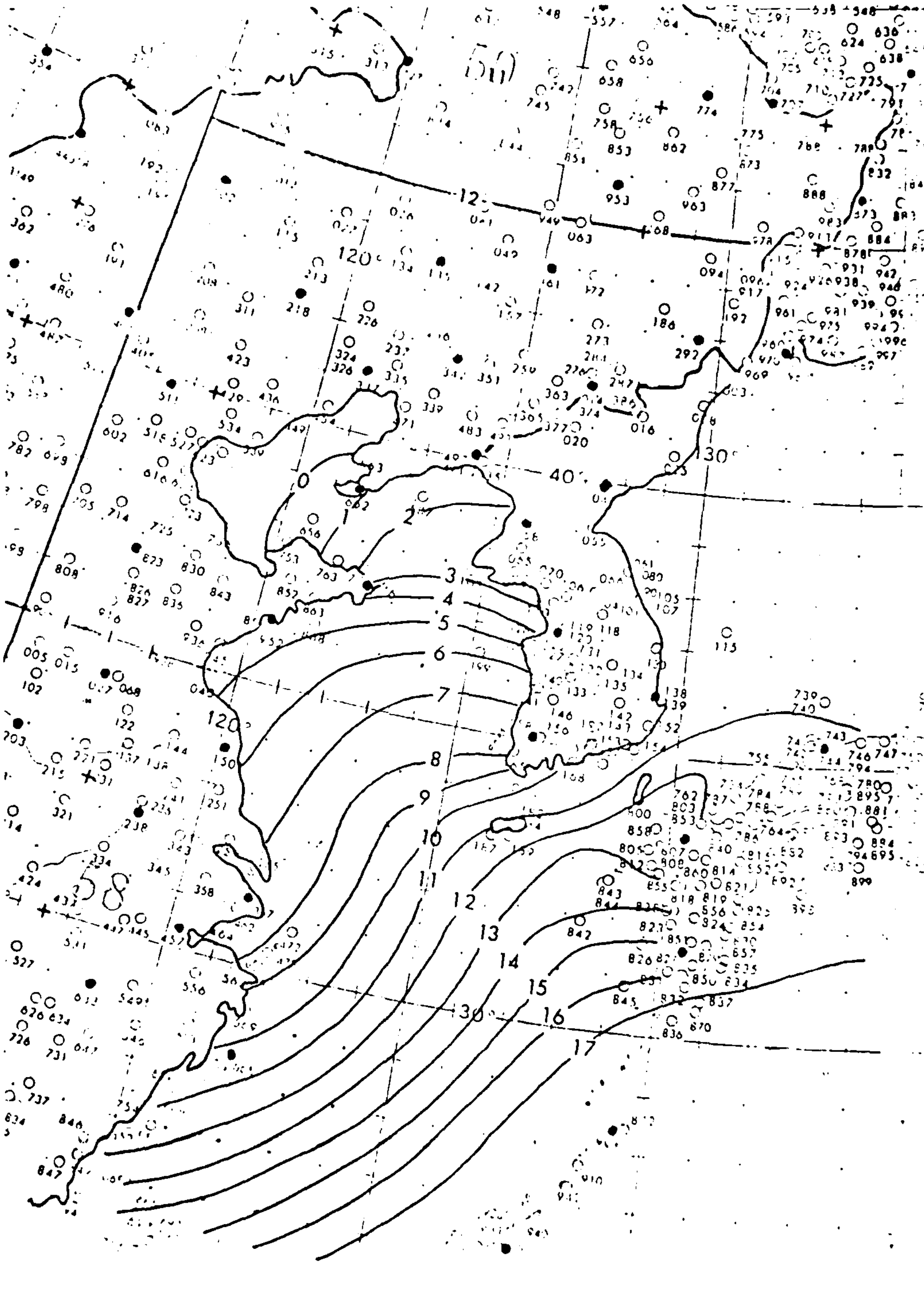

Figure B5. Mean sea surface temperature climatology (°C) for January.

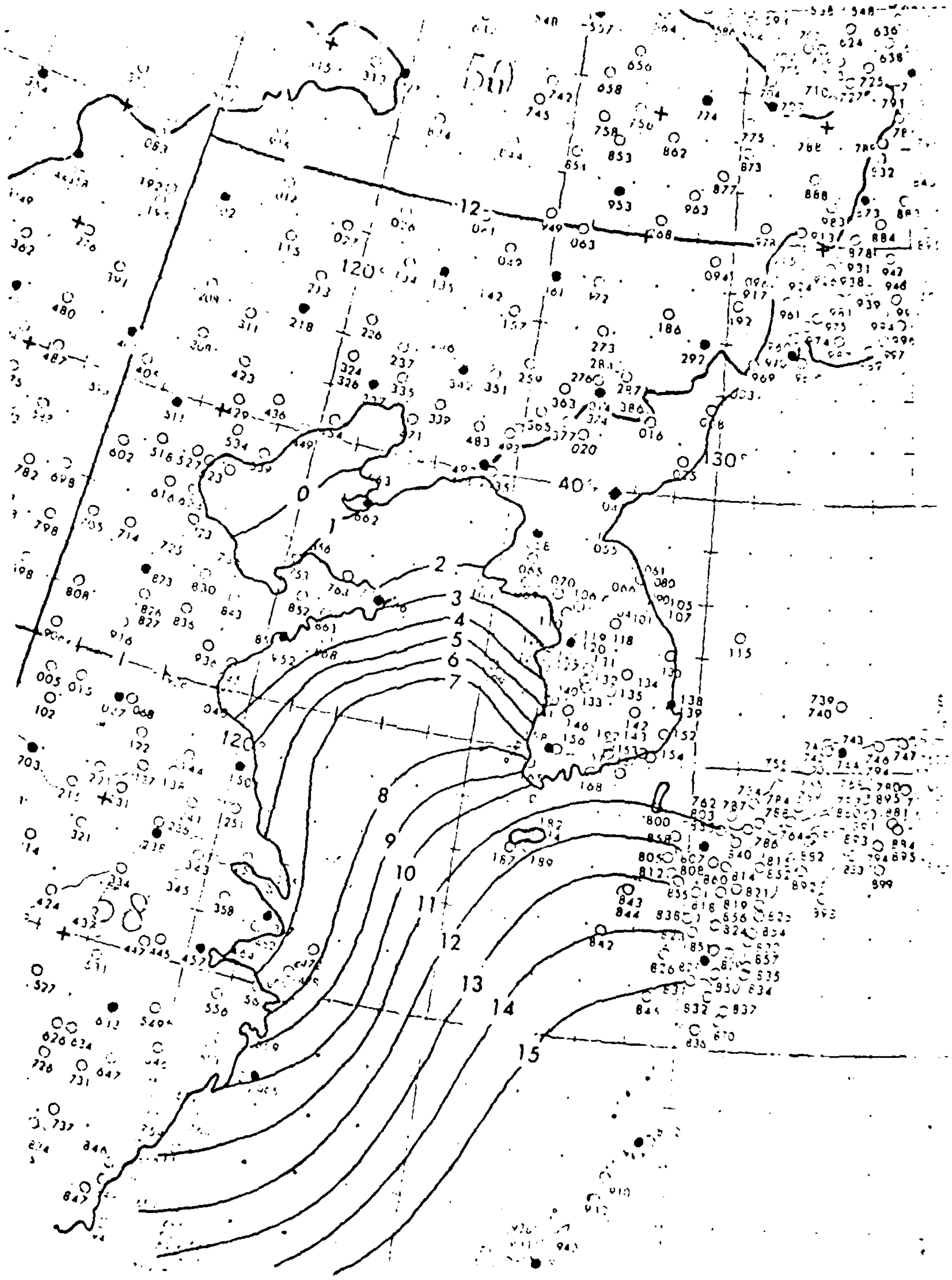

Figure B6. Mean sea surface temperature climatology ($^{\circ}C$) for February.

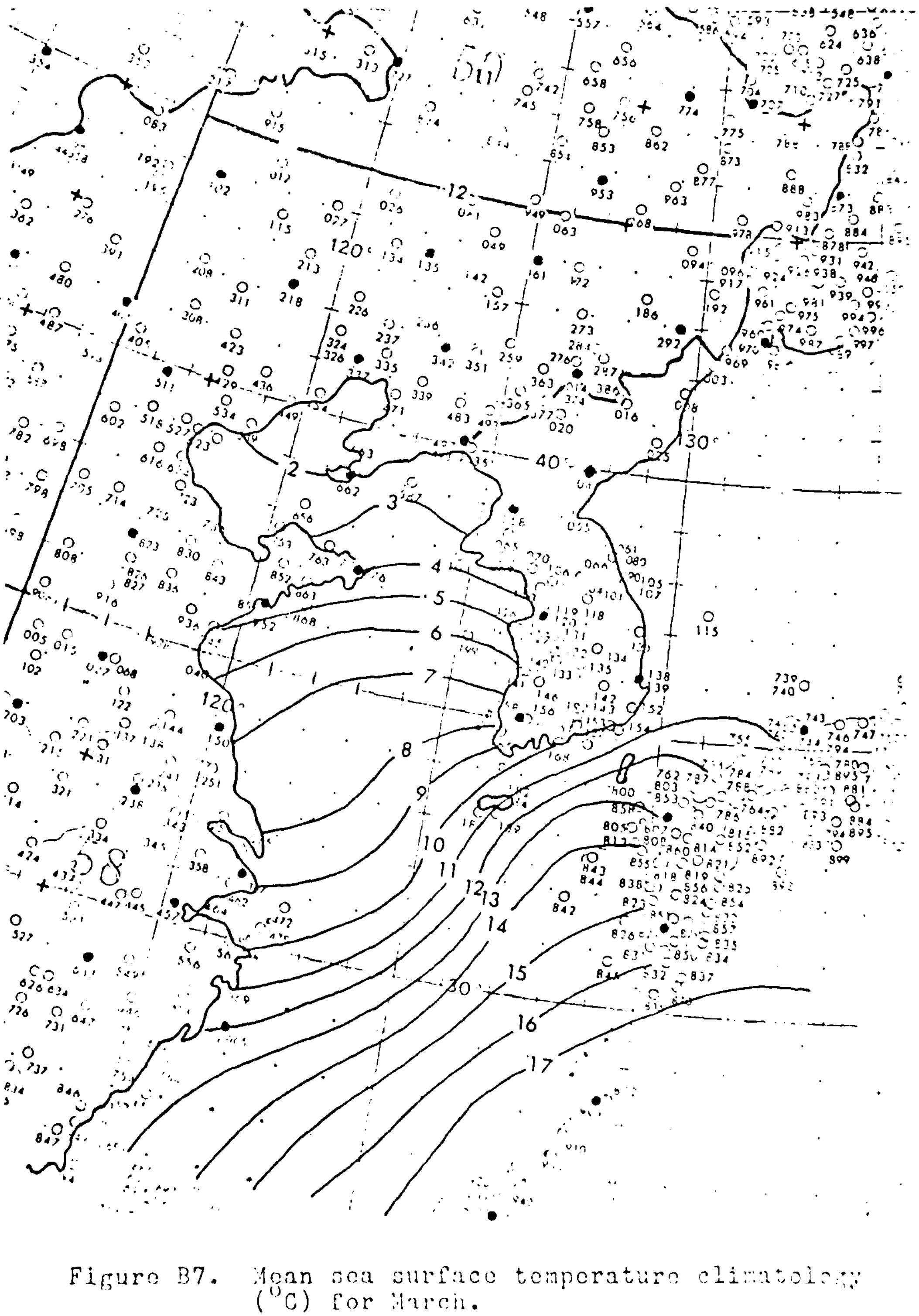

Figure B7. Mean sea surface temperature climatology (^{o}C) for March.

APPENDIX C

DEVELOPMENTAL DATA FROM NOVEMBER 1981 THROUGH FEBRUARY 1982

Tables C1-C8 list the developmental data for the linear regression analyses of cloud amount and stability parameter. Cases used in the analysis are denoted by an asterisk (*). The symbols are defined as follows:

1. N: cloud amount.
2. T_s: sea surface temperature at the test point in °C.
3. T_8: 850 mb temperature at the test point in °C.
4. Z_8: 850 mb height at the test point in meters.
5. γ: boundary layer stability parameter in °C/km.
6. N_m: cloud amount from the regression equation for γ.
7. ΔN: error in cloud amount from regression equation for γ.

Table C1. November 1981 data for 0000Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	-	15.4					
2	-	15.2					
3	-	15.1					
4	-	15.0					
5	-	14.8					
6	*6.0	14.6	-1.5	1555	13.2	9.0	3.0
7	-	14.5					
8	9.0	14.4	-10.5	1545	16.1	9.0	0.0
9	-	14.2					
10	*6.0	14.0	-5.5	1510	12.9	9.0	3.0
11	-	13.9					
12	*2.0	13.8	0.0	1520	9.1	2.6	0.6
13	*0.5	13.6	2.0	1530	7.6	0.0	-0.5
14	0.0	13.4	1.5	1525	7.8	0.0	0.0
15	-	17.3					
16	0.0	13.1	1.5	1470	7.9	0.0	0.0
17	9.0	13.0	-3.5	1500	11.0	6.7	-2.3
18	9.0	12.9	-1.0	1525	9.1	2.6	-6.4
19	(8.0)	12.8					
20	-	12.6					
21	*3.0	12.5	-1.5	1520	9.2	2.8	-0.2
22	-	12.4					
23	-	12.3					
24	-	12.1					
25	*2.0	12.0	-1.0	1530	8.5	1.3	-0.7
26	-	11.9					
27	*8.5	11.7	-2.5	1520	9.3	3.0	-5.5
28	*7.5	11.6	-6.5	1525	11.9	8.6	1.1
29	-	11.5					
30	-	11.4					

Table C2. November 1981 data for 1200Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	-	15.4					
2	-	15.2					
3	-	15.1					
4	-	15.0					
5	*4.0	14.8	-3.8	1560	11.4	7.5	3.5
6	9.0	14.6	-4.5	1566	12.2	9.0	0.0
7	9.0	14.5	-12.0	1566	16.9	9.0	0.0
8	9.0	14.4	-10.5	1540	16.2	9.0	0.0
9	*7.5	14.2	-7.0	1521	13.9	9.0	1.5
10	-	14.0					
11	*1.0	13.9	-1.5	1530	10.1	4.7	3.6
12	0.0	13.8	1.0	1523	8.4	1.1	1.1
13	0.0	13.6	1.5	1531	7.9	0.0	0.0
14	0.0	13.4	4.0	1503	6.3	0.0	0.0
15	*0.5	13.3	1.5	1460	8.1	0.4	-0.1
16	-	13.1					
17	*8.0	13.0	-3.0	1520	10.5	5.6	-2.4
18	*5.0	12.9	0.5	1525	8.1	0.4	-4.6
19	-	12.8					
20	*2.0	12.6	0.0	1509	8.3	0.8	-1.2
21	0.0	12.5	1.0	1525	7.5	0.0	0.0
22	-	12.4					
23	0.0	12.3	0.0	1501	8.2	0.6	0.6
24	*1.5	12.1	-1.5	1524	8.9	2.1	0.6
25	-	12.0					
26	*4.0	11.9	-1.5	1516	8.8	1.9	-2.1
27	*8.0	11.7	-7.0	1514	12.4	9.0	1.0
28	*4.0	11.6	-5.0	1549	10.7	6.0	2.0
29	-	11.5					
30	*8.0	11.4	-9.0	1548	13.2	9.0	1.0

Table C3. December 1981 data for 0000Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	9.0	11.3	-15.0	1525	17.2	9.0	0.0
2	*8.0	11.1	-8.4	1560	12.6	9.0	1.0
3	9.0	11.0	-5.0	1575	10.2	4.9	-4.1
4	*5.0	10.9	-4.0	1545	9.6	3.6	-1.4
5	*5.0	10.7	-4.5	1525	10.0	4.5	-0.5
6	*5.0	10.6	-6.5	1510	11.3	7.3	2.3
7	*5.0	10.5	-6.0	1480	11.1	6.9	1.9
8	*3.0	10.4	-5.0	1495	10.3	5.1	2.1
9	*1.0	10.2	-2.0	1535	7.9	0.0	-1.0
10	*5.5	10.1	-1.5	1545	7.5	0.0	-5.5
11	*5.0	10.0	-1.5	1490	7.7	0.0	-5.0
12	*7.0	9.8	-6.0	1500	10.5	5.6	-1.4
13	*7.5	9.7	-6.0	1535	10.2	4.9	-2.6
14	9.0	9.6	-9.5	1510	12.6	9.0	0.0
15	*7.0	9.4	-9.0	1535	12.0	8.8	1.8
16	-	9.4					
17	*3.0	9.3	-4.5	1590	8.7	1.7	-1.3
18	-	9.3					
19	9.0	9.2	-6.0	1455	10.4	5.4	-3.6
20	*6.5	9.2	-3.5	1480	8.6	1.5	-5.0
21	*4.5	9.1	-2.0	1505	7.4	0.0	-4.5
22	-	9.1					
23	*5.5	9.0	-6.0	1460	10.3	5.2	-0.3
24	*0.5	9.0	-5.0	1500	9.3	3.0	2.5
25	*2.0	8.9	-1.5	1510	6.9	0.0	-2.0
26	*1.0	8.8	-3.0	1480	8.0	0.2	-0.8
27	-	8.8					
28	-	8.7					
29	9.0	8.7	-7.5	1470	11.0	6.7	-2.3
30	-	8.6					
31	*7.0	8.6	-10.0	1465	12.7	9.0	2.0

Table C4. December 1981 data for 1200Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	9.0	11.3	-15.0	1541	17.1	9.0	0.0
2	*5.0	11.1	-6.0	1578	10.8	6.2	1.2
3	-	11.0					
4	*7.5	10.0	-4.0	1520	9.8	4.1	-3.4
5	*3.0	10.7	-4.0	1526	9.6	3.6	0.6
6	*6.5	10.6	-5.0	1505	10.4	5.4	-1.1
7	*4.5	10.5	-4.5	1509	9.9	4.3	-0.2
8	*4.0	10.4	-4.0	1521	9.5	3.4	-0.6
9	*2.5	10.2	-2.0	1541	7.9	0.0	-2.5
10	-	10.1					
11	-	10.0					
12	-	9.8					
13	9.0	9.7	-11.5	1542	13.7	9.0	0.0
14	9.0	9.6	-12.0	1530	14.1	9.0	0.0
15	*7.5	9.4	-7.0	1550	10.6	5.8	-1.7
16	-	9.4					
17	*3.5	9.3	-5.0	1593	9.0	2.4	-1.1
18	-	9.3					
19	9.0	9.2	-9.5	1463	12.8	9.0	0.0
20	*3.5	9.2	-2.0	1497	7.5	0.0	-3.5
21	0.0	9.1	-1.0	1510	6.7	0.0	0.0
22	-	9.1					
23	*4.0	9.0	-9.0	1491	12.1	9.0	5.0
24	0.0	9.0	-2.0	1518	7.2	0.0	0.0
25	0.0	8.9	1.5	1501	4.9	0.0	0.0
26	0.0	8.8	4.0	1472	3.3	0.0	0.0
27	0.0	8.8	2.0	1482	4.6	0.0	0.0
28	0.0	8.7	0.0	1475	5.9	0.0	0.0
29	*7.5	8.7	-7.5	1484	10.9	6.5	-0.9
30	-	8.6					
31	*8.0	8.6	-10.0	1479	12.6	9.0	1.0

Table C5. January 1982 data for 0000Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	*8.0	8.5	-10.0	1480	12.5	9.0	1.0
2	*2.0	8.4	-7.0	1525	10.1	4.7	2.7
3	0.0	8.3	-1.0	1525	6.1	0.0	0.0
4	0.0	8.2	-2.8	1480	7.4	0.0	0.0
5	*4.5	8.1	-7.0	1490	10.1	4.7	0.2
6	-	8.0					
7	*8.5	8.0	-7.5	1520	10.2	4.9	-3.6
8	*8.0	7.9	-7.0	1455	10.2	4.9	-3.1
9	*2.5	7.8	-4.5	1440	8.5	1.3	-1.2
10	0.0	7.8	-3.0	1455	7.4	0.0	0.0
11	0.0	7.7	0.0	1430	5.4	0.0	0.0
12	9.0	7.6	-15.0	1475	15.3	9.0	0.0
13	*8.0	7.6	-10.5	1465	12.4	9.0	1.0
14	*5.0	7.5	-10.0	1460	12.0	8.8	3.8
15	9.0	7.4	-11.0	1460	12.6	9.0	0.0
16	9.0	7.4	-16.0	1450	16.1	9.0	0.0
17	9.0	7.4	-11.0	1460	12.6	9.0	0.0
18	9.0	7.3	-15.0	1420	15.7	9.0	0.0
19	9.0	7.3	-12.5	1440	13.8	9.0	0.0
20	*4.0	7.3	-8.0	1470	10.4	5.4	1.4
21	0.0	7.2	-2.0	1475	6.2	0.0	0.0
22	-	7.2					
23	-	7.2					
24	-	7.2					
25	-	7.2					
26	*4.0	7.1	-6.5	1520	8.9	2.1	-1.9
27	9.0	7.1	-12.0	1480	12.9	9.0	0.0
28	9.0	7.1	-19.0	1485	17.6	9.0	0.0
29	9.0	7.0	-17.5	1510	16.2	9.0	0.0
30	*7.5	7.0	-9.0	1510	10.6	5.8	-1.7
31	-	7.0					

Table C6. January 1982 data for 1200Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	*2.0	8.5	-8.0	1500	11.0	6.7	4.7
2	0.0	8.4	-4.0	1540	8.0	0.2	0.2
3	0.0	8.3	3.0	1490	3.6	0.0	0.0
4	*0.5	8.2	-5.5	1485	9.2	2.8	2.3
5	*3.0	8.1	-5.5	1485	9.2	2.8	-0.2
6	*8.0	8.0	-9.0	1505	11.3	7.3	-0.7
7	*3.5	8.0	-4.5	1505	8.3	0.8	-2.7
8	*2.5	7.9	-5.0	1435	9.0	2.4	-0.1
9	0.0	7.8	-3.0	1460	7.4	0.0	0.0
10	0.0	7.8	1.5	1460	4.3	0.0	0.0
11	9.0	7.7	-6.0	1450	9.4	3.2	-5.8
12	9.0	7.6	-10.5	1470	12.3	9.0	0.0
13	9.0	7.6	-12.0	1470	13.3	9.0	0.0
14	*6.0	7.5	-9.0	1460	11.3	7.3	1.3
15	9.0	7.4	-13.5	1460	14.3	9.0	0.0
16	9.0	7.4	-15.0	1480	15.1	9.0	0.0
17	9.0	7.4	-13.0	1445	14.1	9.0	0.0
18	9.0	7.3	-17.0	1430	17.0	9.0	0.0
19	*7.0	7.3	-10.0	1460	11.8	8.4	1.4
20	*2.0	7.3	-7.5	1480	10.0	4.5	2.5
21	0.0	7.2	-2.0	1465	6.3	0.0	0.0
22	*3.0	7.2	-5.0	1465	8.3	0.8	-2.2
23	0.0	7.2	-1.0	1520	5.4	0.0	0.0
24	*0.5	7.2	-4.0	1515	7.4	0.0	-0.5
25	0.0	7.2	-4.0	1540	7.3	0.0	0.0
26	*8.0	7.1	-8.0	1515	10.0	4.5	-3.5
27	9.0	7.1	-17.0	1485	16.2	9.0	0.0
28	9.0	7.1	-16.0	1510	15.3	9.0	0.0
29	*8.0	7.0	-13.0	1515	13.2	9.0	1.0
30	*3.5	7.0	-8.5	1507	10.3	5.2	1.7
31	*6.0	7.0	-10.0	1460	11.6	8.0	2.0

Table C7. February 1982 data for 0000Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	*2.5	7.0	-9.0	1470	10.9	6.5	4.0
2	*5.5	6.9	-8.0	1505	9.9	4.3	-1.2
3	-	6.9					
4	-	6.9					
5	9.0	6.9	-9.0	1465	10.9	6.5	-2.5
6	9.0	6.9	-11.5	1445	12.7	9.0	0.0
7	*8.0	6.9	-12.5	1485	13.1	9.0	1.0
8	*8.0	6.8	-11.0	1498	11.9	8.6	0.6
9	*4.5	6.8	-7.0	1497	9.2	2.8	-1.7
10	-	6.8					
11	-	6.8					
12	0.0	6.8					
13	-	6.8					
14	-	6.7					
15	*1.5	6.7	-4.5	1500	7.5	0.0	-1.5
16	*2.0	6.7	-4.5	1495	7.5	0.0	-2.0
17	-	6.7					
18	-	6.7					
19	0.0	6.7					
20	0.0	6.7					
21	0.0	6.6					
22	0.0	6.6					
23	0.0	6.6					
24	0.0	6.6					
25	0.0	6.5					
26	0.0	6.5					
27	0.0	6.5					
28	0.0	6.5					

Table C8. February 1982 data for 1200Z.

Day	N	T_s	T_8	Z_8	γ	N_m	ΔN
1	*5.5	7.0	-10.0	1508	11.3	7.3	1.8
2	-	6.9					
3	-	6.9					
4	*4.5	6.9	-12.0	1484	12.7	9.0	4.5
5	*7.5	6.9	-12.0	1475	12.8	9.0	1.5
6	9.0	6.9	-15.0	1490	14.7	9.0	0.0
7	-	6.9					
8	*4.5	6.8	-9.0	1520	10.4	5.4	0.9
9	*6.5	6.8	-11.0	1517	11.7	8.2	1.7
10	0.0	6.8	-5.0	1519	7.8	0.0	0.0
11	0.0	6.8	-3.5	1508	6.8	0.0	0.0
12	0.0	6.8	-4.0	1533	7.0	0.0	0.0
13	*3.5	6.8	-6.0	1526	8.4	1.1	-2.4
14	*1.5	6.7	-5.0	1514	7.7	0.0	-1.5
15	0.0	6.7	-4.0	1505	7.1	0.0	0.0
16	0.0	6.7	-2.0	1488	5.8	0.0	0.0
17	0.0	6.7	-2.0	1524	5.7	0.0	0.0
18	-	6.7					
19	0.0	6.7	-1.0	1442	5.3	0.0	0.0
20	0.0	6.7	-2.0	1458	6.0	0.0	0.0
21	0.0	6.6	-2.0	1485	5.8	0.0	0.0
22	0.0	6.6	0.0	1510	4.4	0.0	0.0
23	0.0	6.6	-2.0	1480	5.8	0.0	0.0
24	0.0	6.6	-5.0	1495	7.8	0.0	0.0
25	0.0	6.5	-4.0	1514	6.9	0.0	0.0
26	0.0	6.5	-4.0	1500	7.0	0.0	0.0
27	0.0	6.5	1.0	1498	3.7	0.0	0.0
28	*3.0	6.5	-6.0	1453	8.6	1.5	-1.5

APPENDIX D

SOUNDINGS OF TEMPERATURE AND DEWPOINT TEMPERATURE

Figures D1-D11 are atmospheric soundings from Kagoshima (31.6°N, 130.5°E), Fukuoka (33.5°N, 130.3°E), Amami-Oshima (28.5°N, 129.5°E), Kwangju (36.1°N, 126.8°E), and Osan (37.1°N, 126.9°E). These soundings show the vertical profile of temperature and dewpoint temperature at each station following a cold air outbreak. In most cases, the soundings resemble the idealized example in Figure 13.

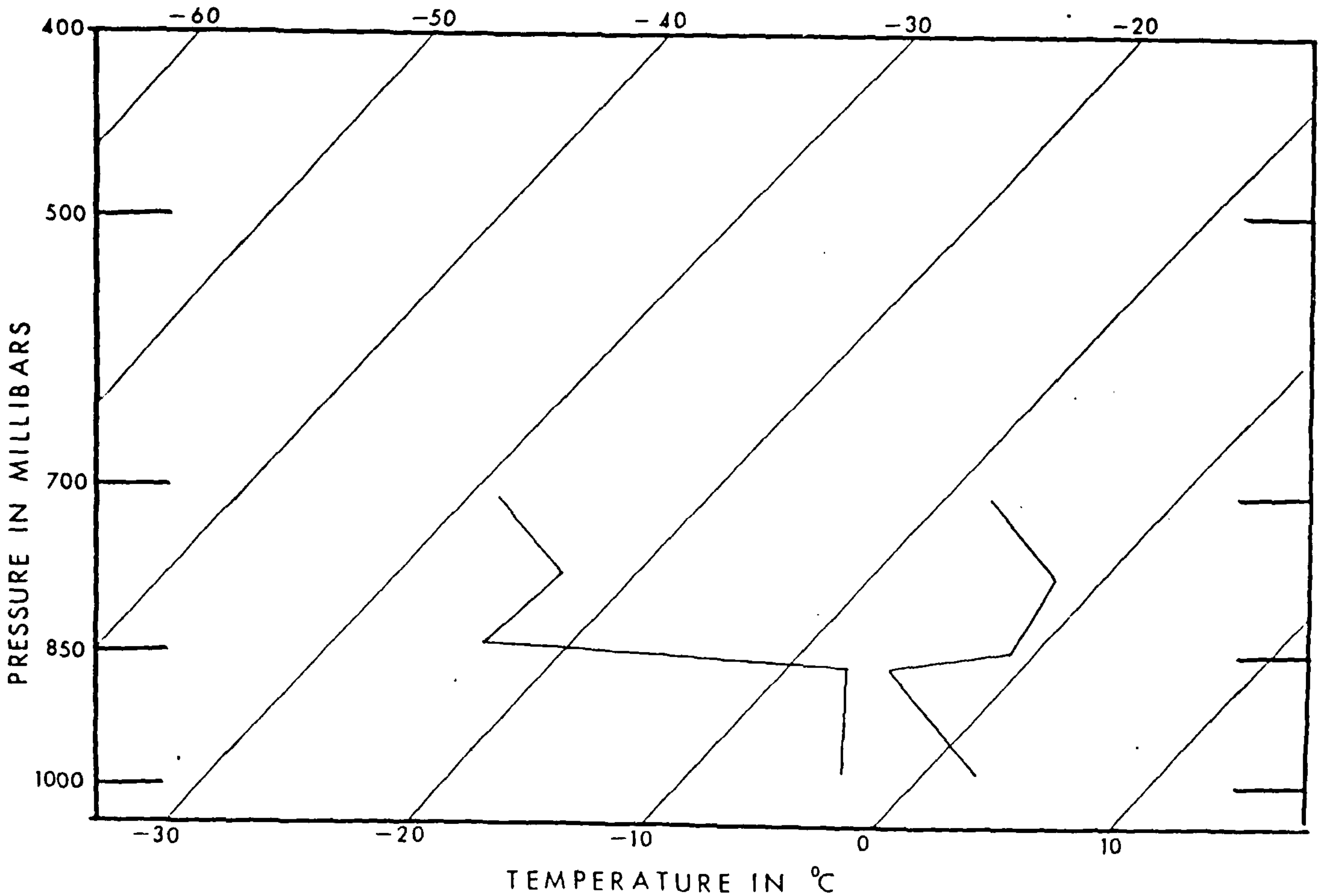

Figure D1. Kagoshima (WMO 47827). 14 January 1982 (0000 GMT)

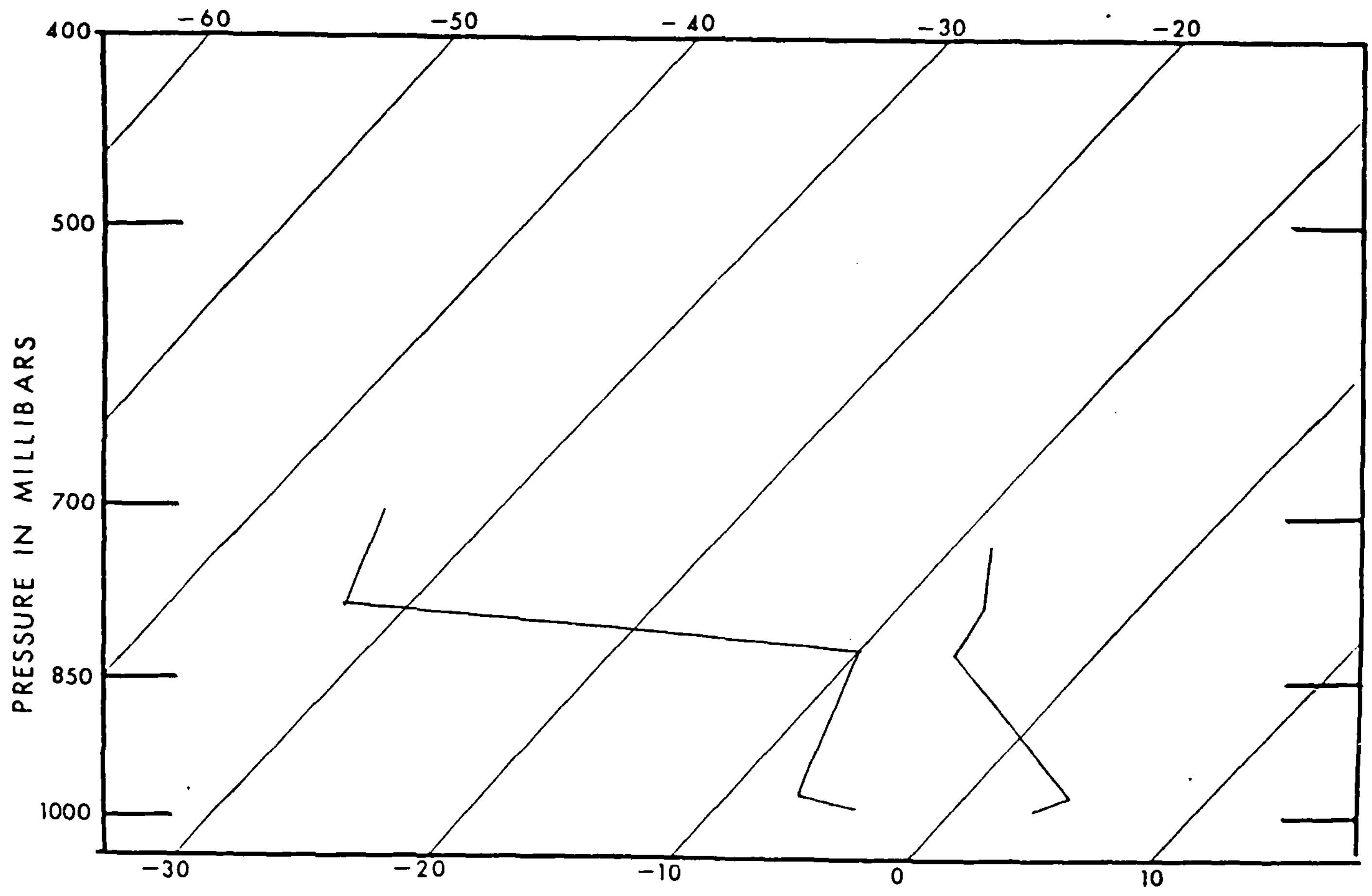

Figure D2. Kagoshima (47827). 7 January 1982 (0000 GMT)

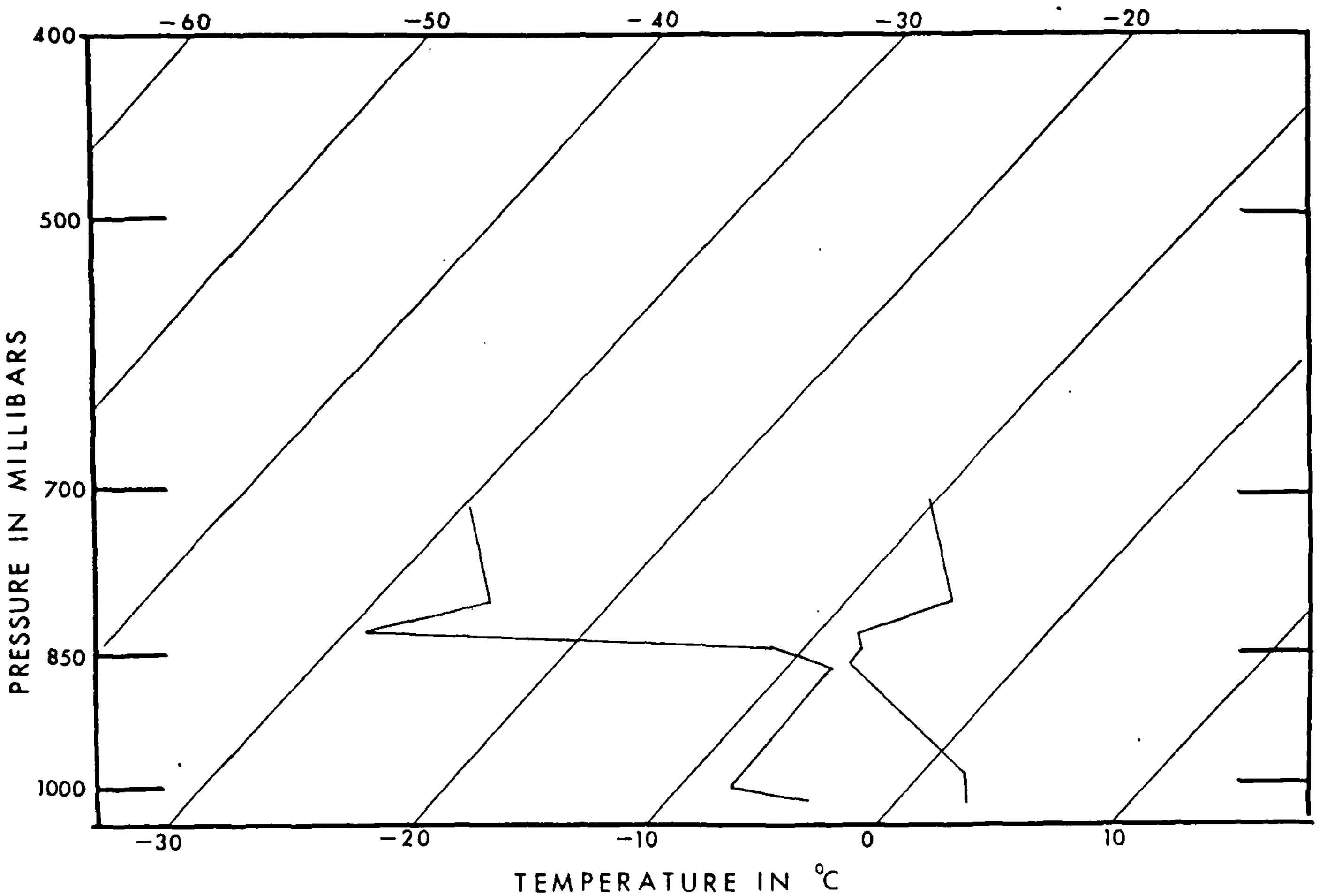

Figure D3. Fukuoka (47807). 14 January 1982 (1200 GMT)

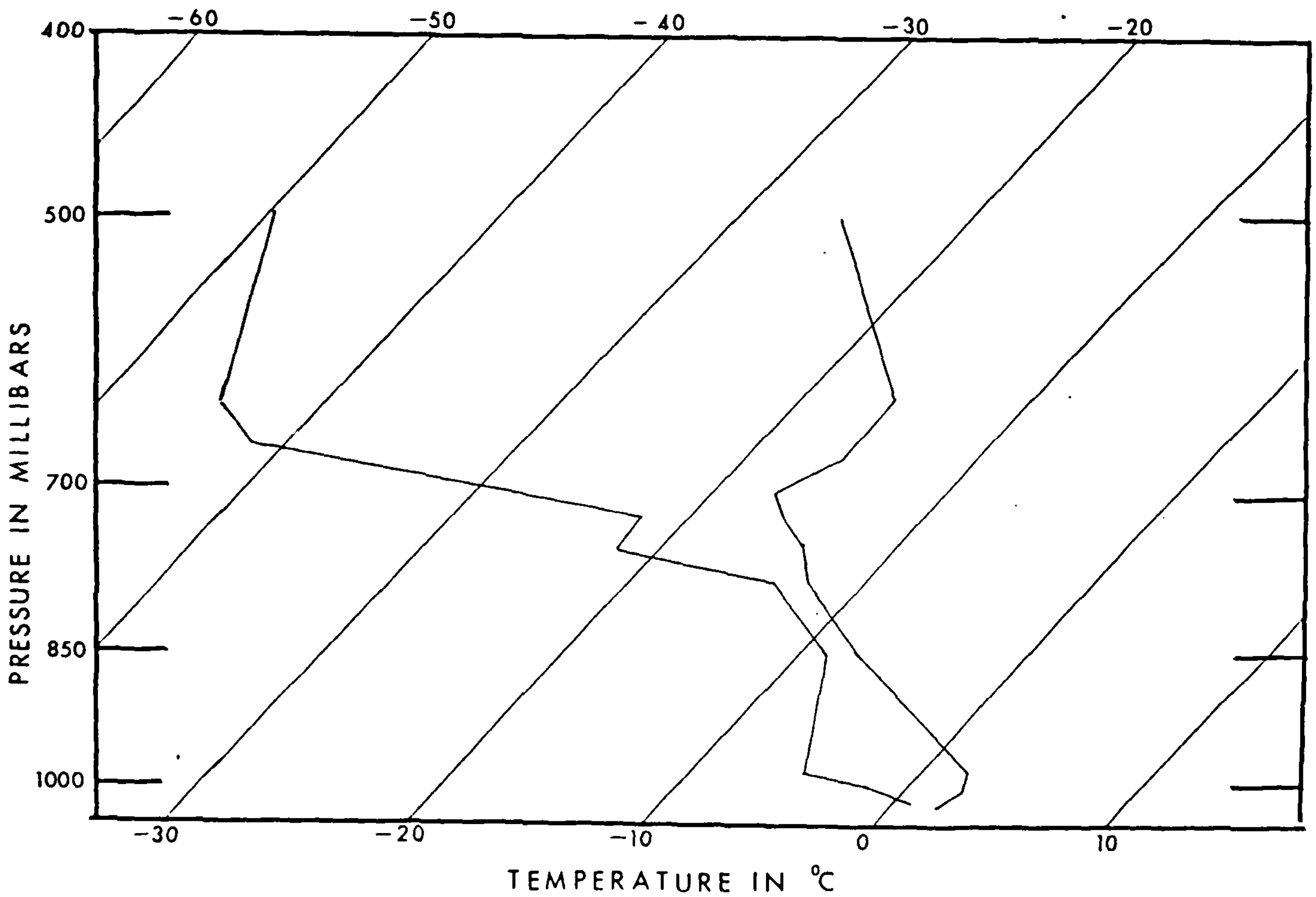

Figure 54. Fukuoka (47807). 15 January 1982 (1200 GMT)

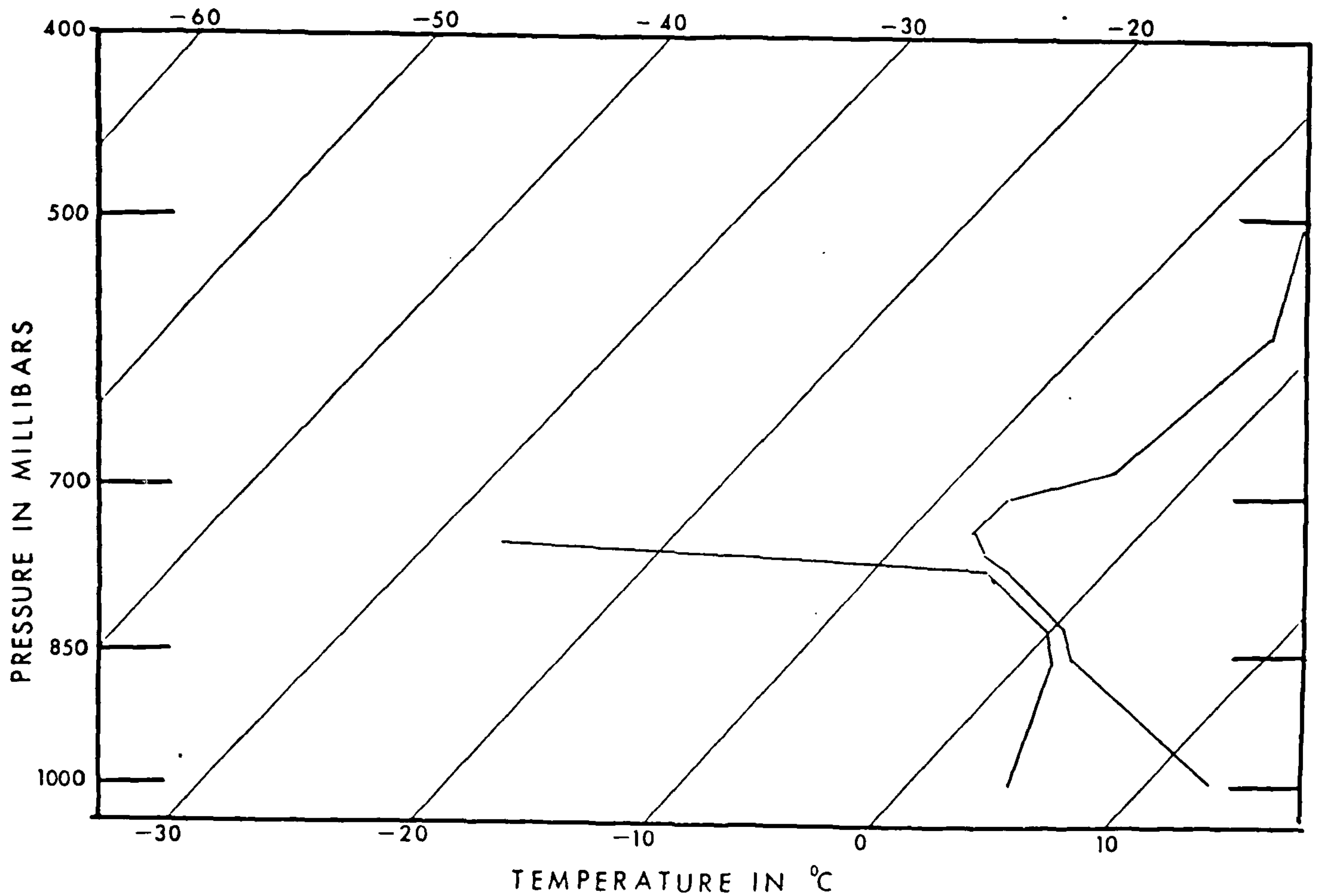

Figure D5. Amami-Oshima (47909). 1 December 1981 (1200 GMT)

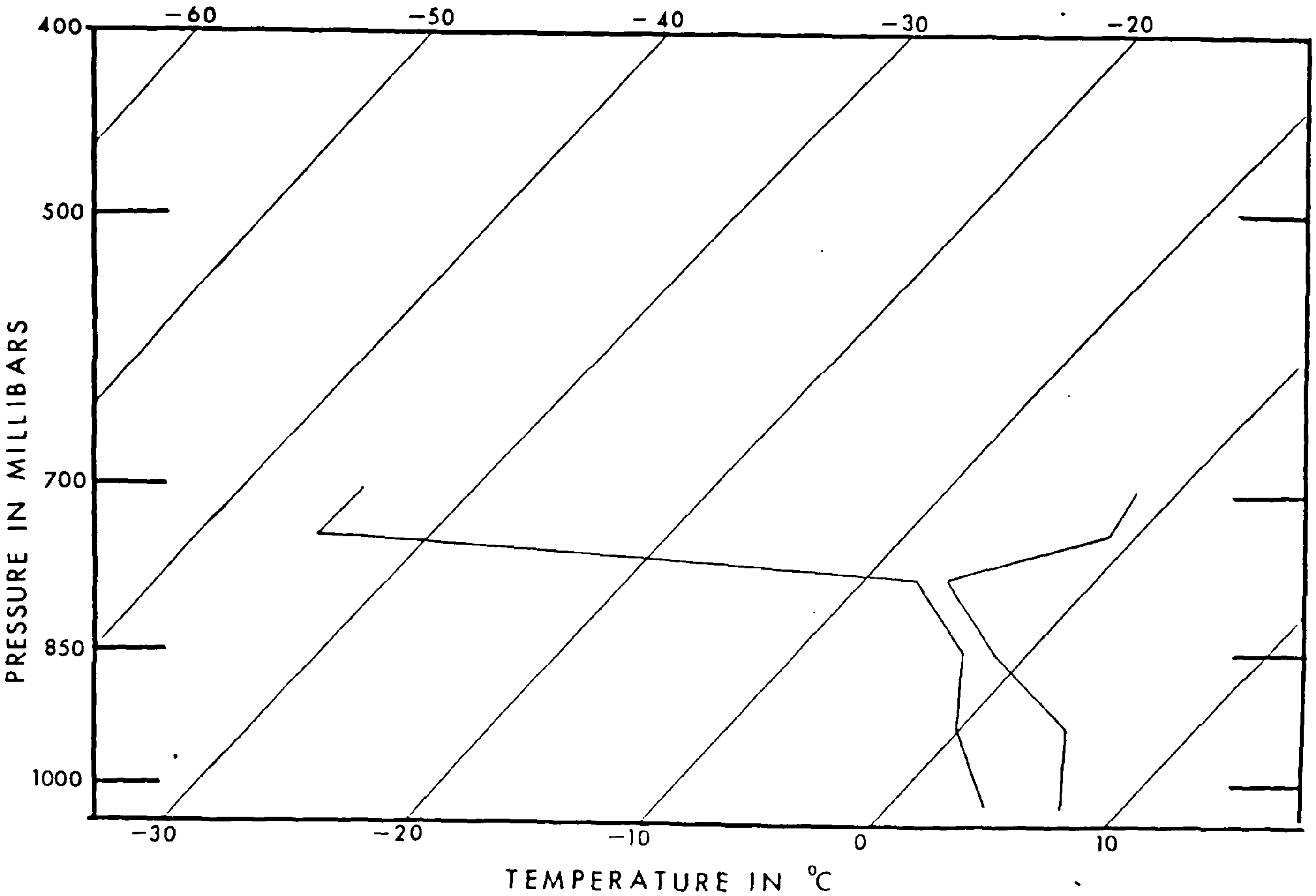

Figure 26. Amami-Oshima (47909). 2 December 1981 (1200 GMT)

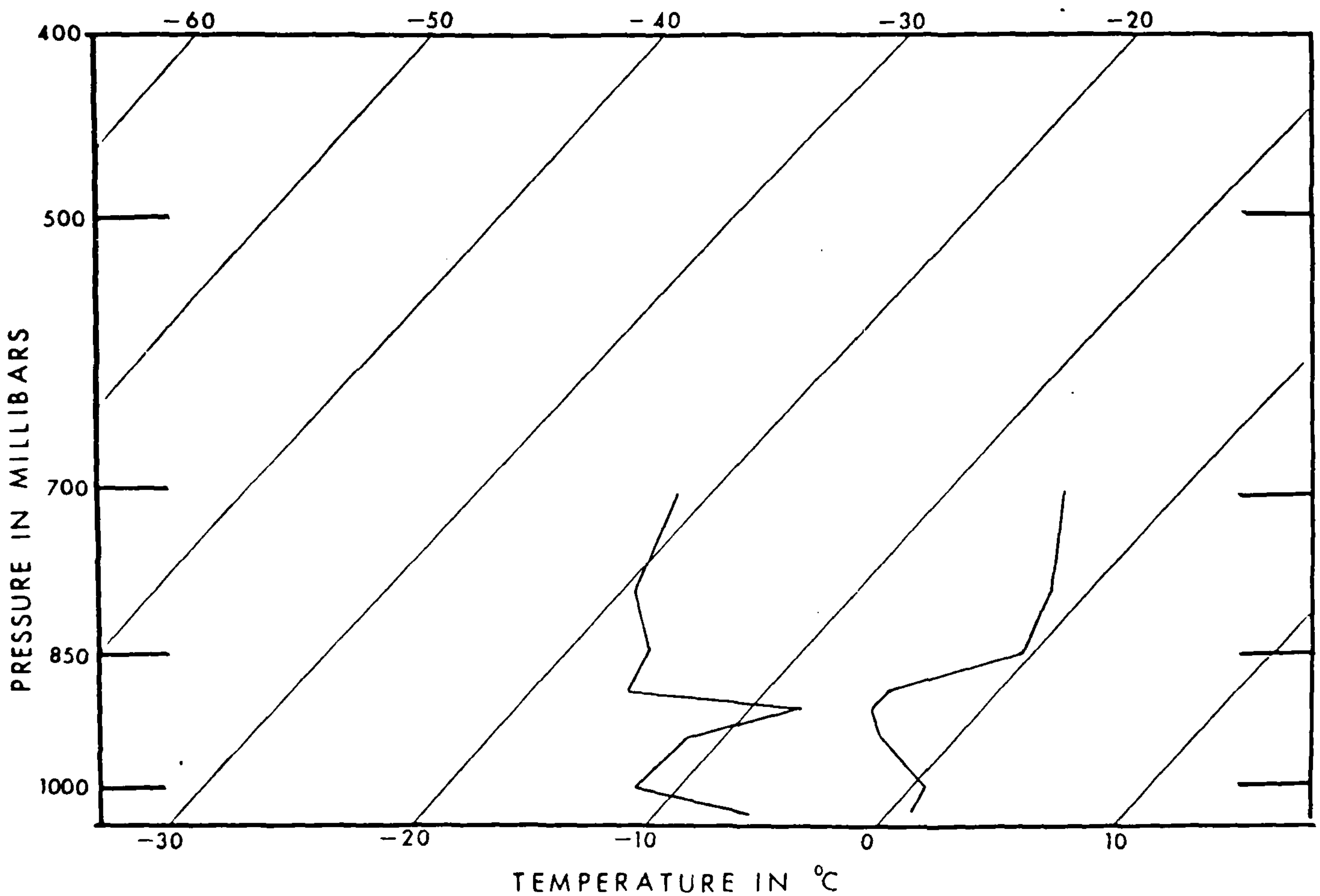

Figure D7. Kwangju (47158). 25 November 1982 (1200 GMT)

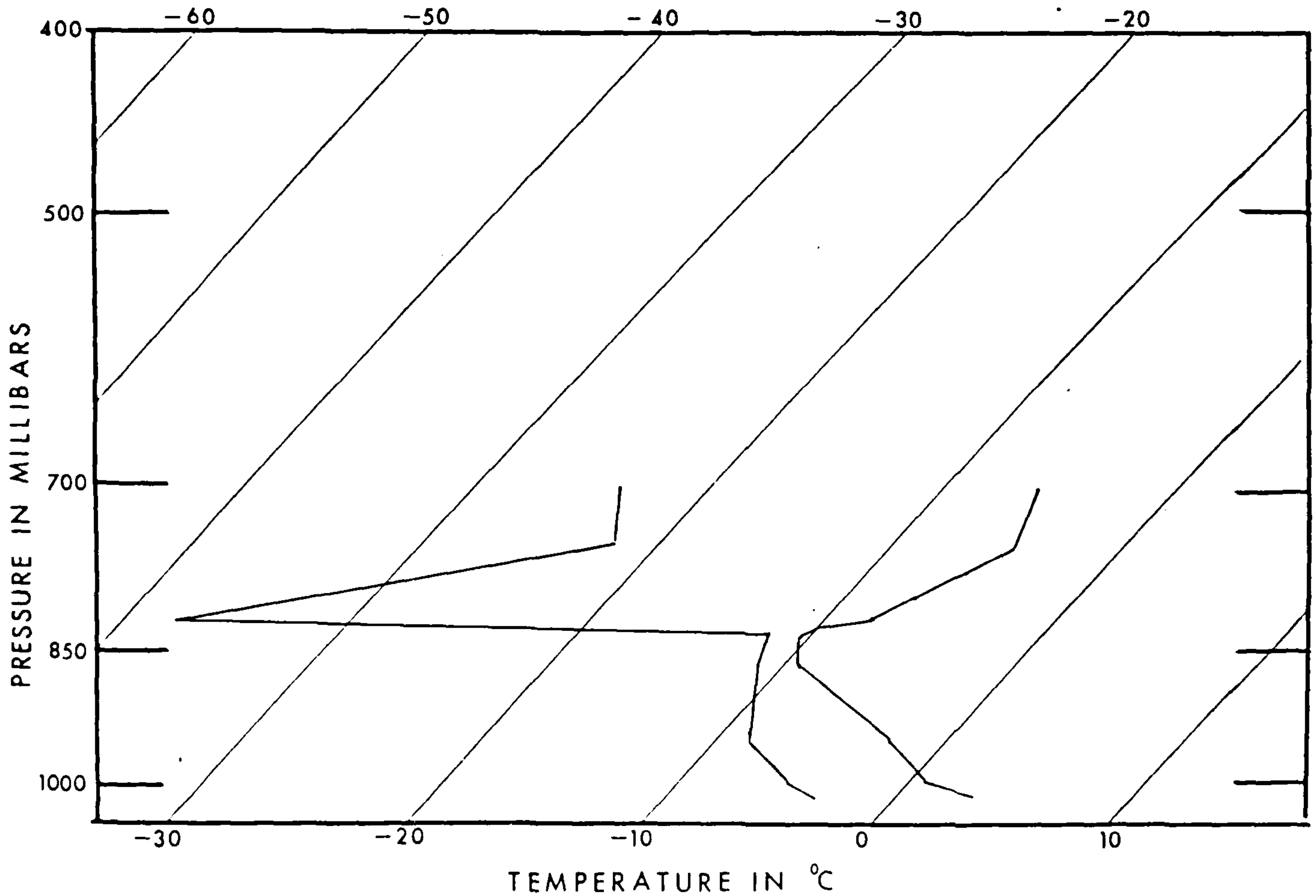

Figure D8. Kwangju (47158). 24 November 1982 (0000 GMT).

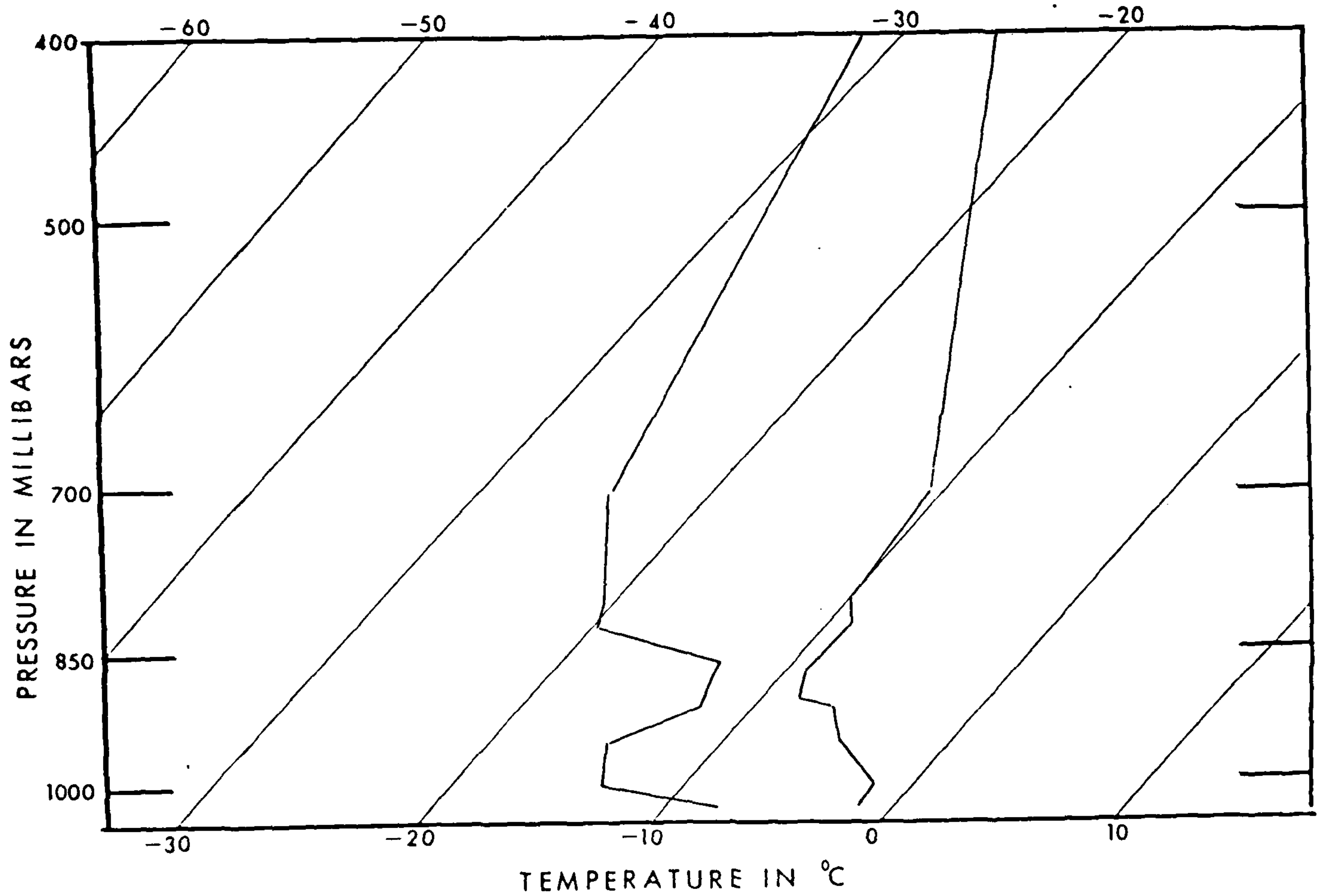

Figure D9. Osan AB (47122). 7 November 1981 (0000 GMT).

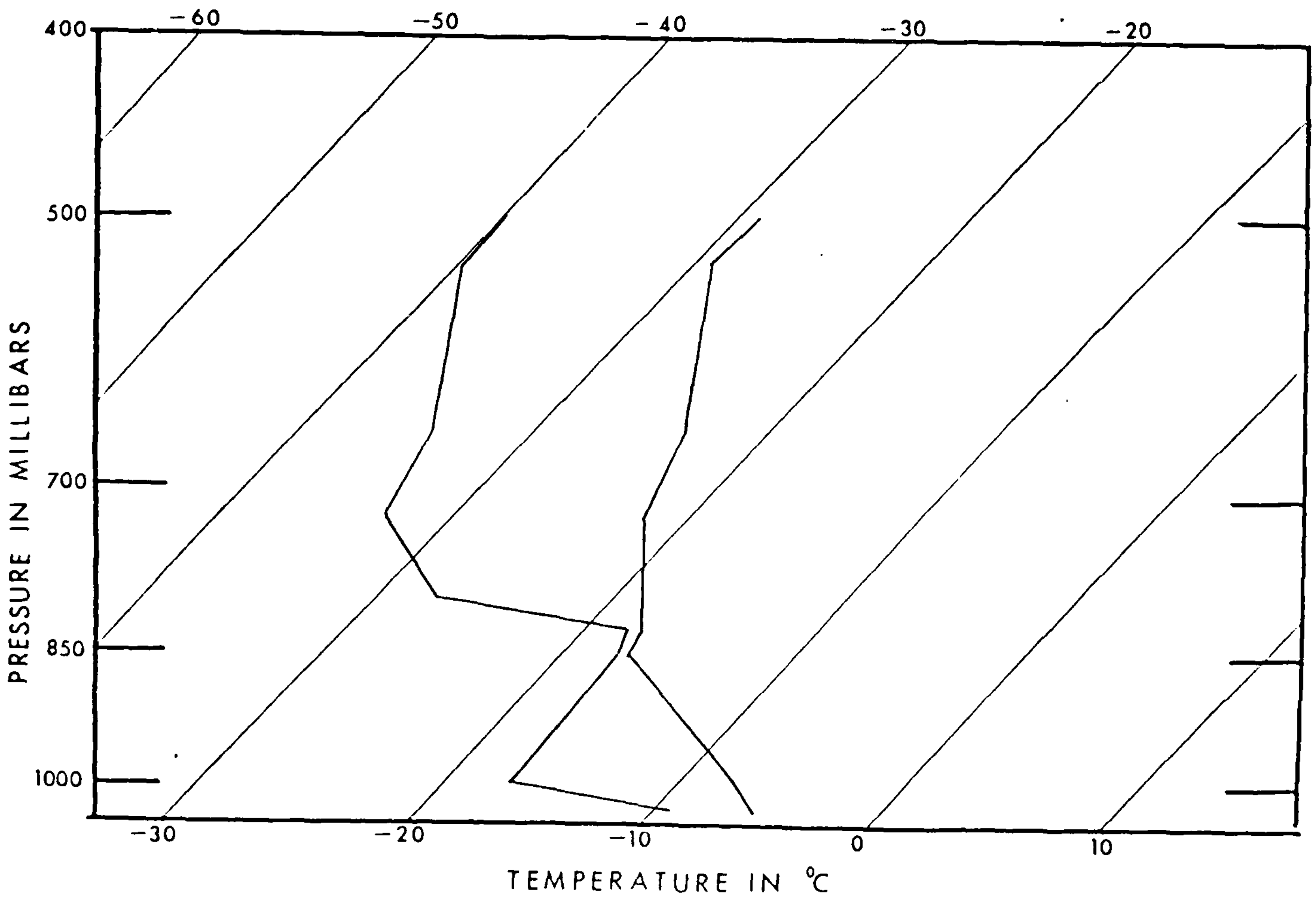

Figure D10. Osan AB (47122). 1 December 1981 (0000 GMT)

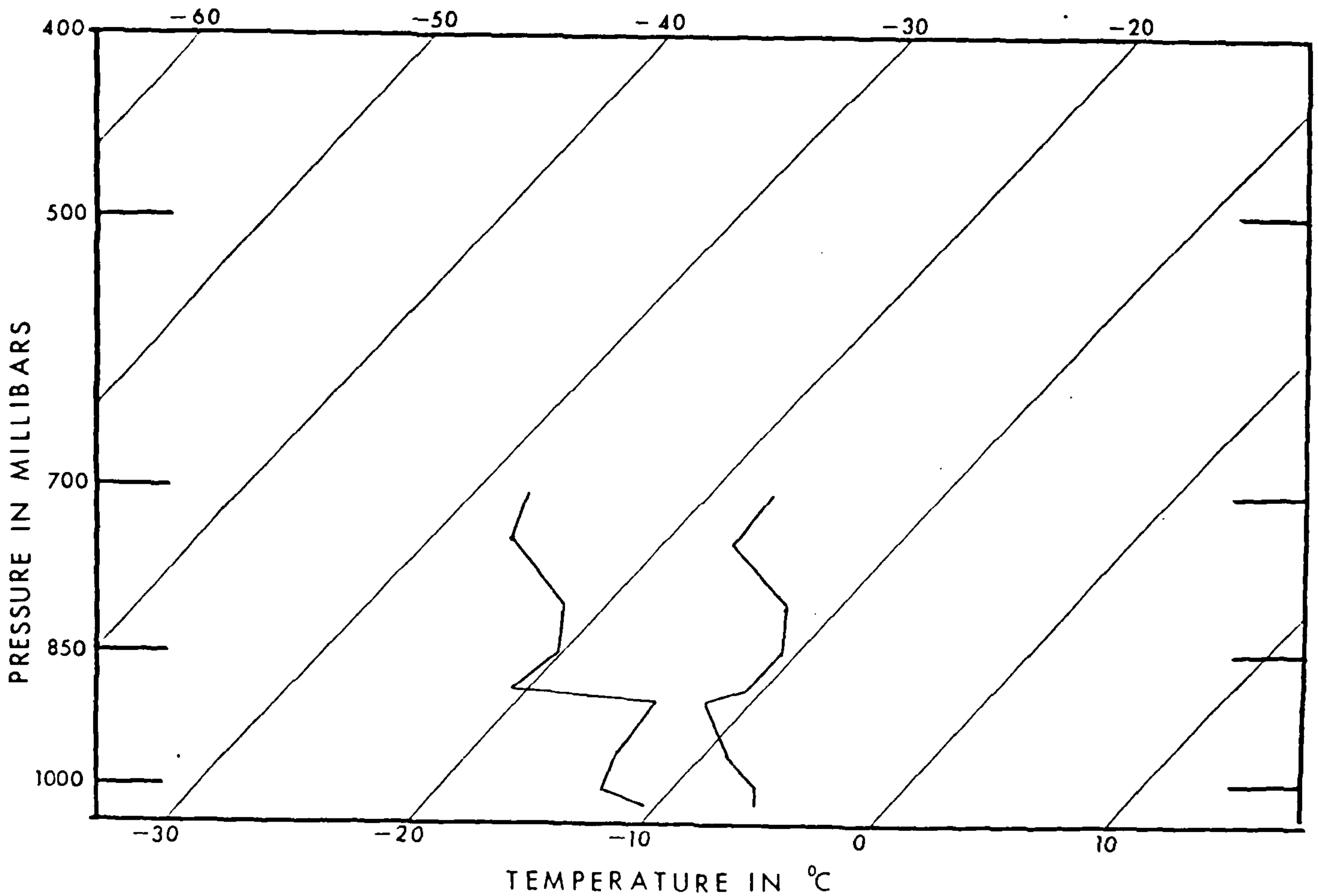

Figure D11. Osan AB (47122). 14 December 1981 (0000 GMT)

APPENDIX E

COLD AIR STRATOCUMULUS
OUTBREAK HISTORIES

Figures E1-E11 are histograms showing the daily average cloud amount over the Yellow Sea, as observed on satellite imagery, during outbreaks of cold air stratocumulus for the winter of 1981-1982. The cloud amounts are valid for a 3x3 array of cells, each 1° latitude by 1° longitude, in an area extending from 34 to 37°N and from 123 to 126°E.

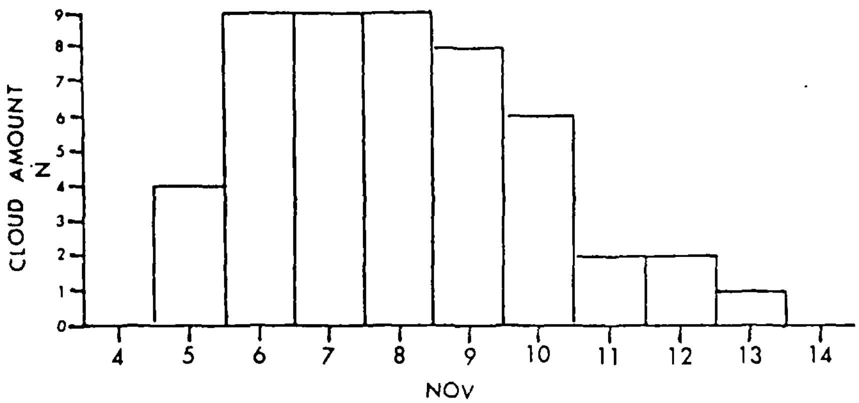

Figure E1. 5-14 November 1981.

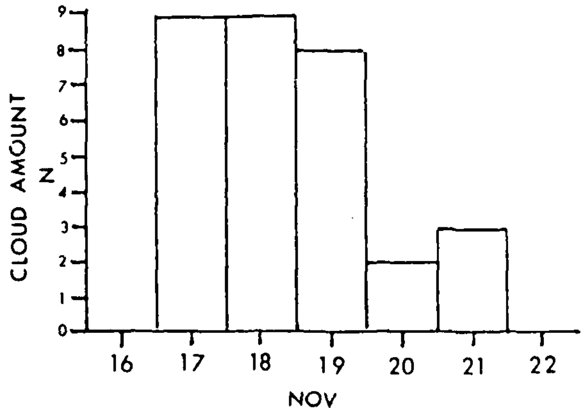

Figure E2. 17-21 November 1981.

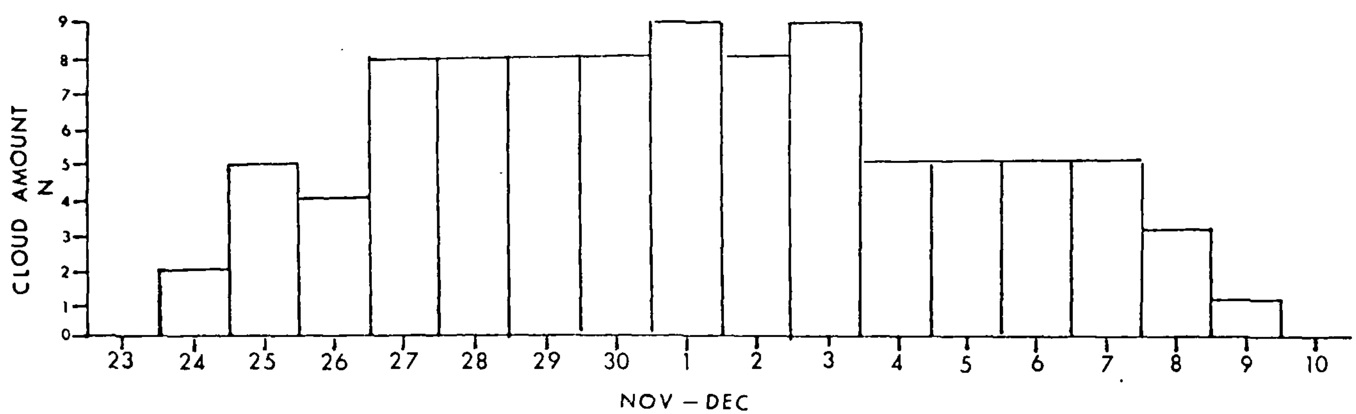

Figure E3. 24 November-8 December 1981.

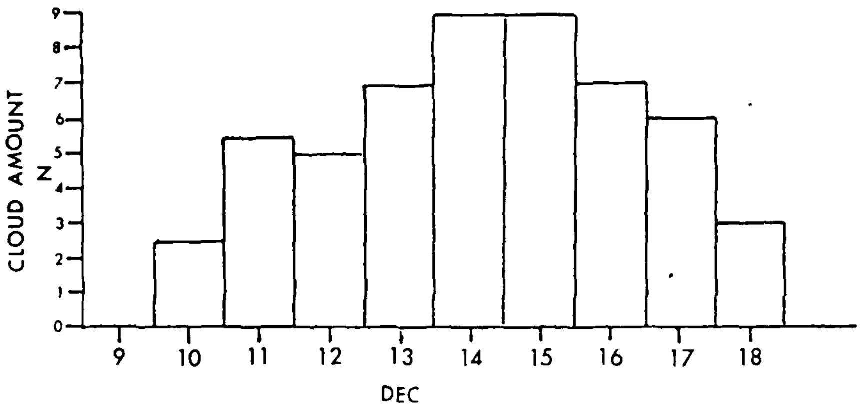

Figure E4. 10-18 December 1981.

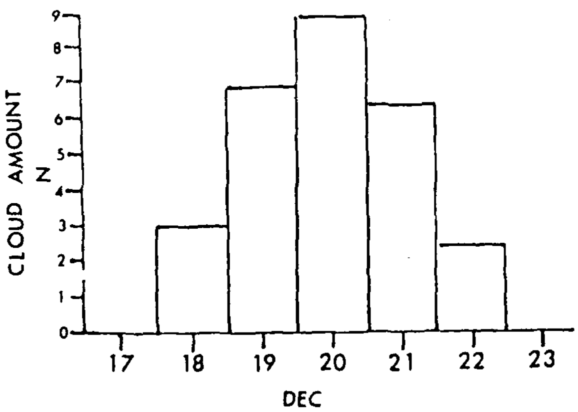

Figure E5. 18-22 December 1981.

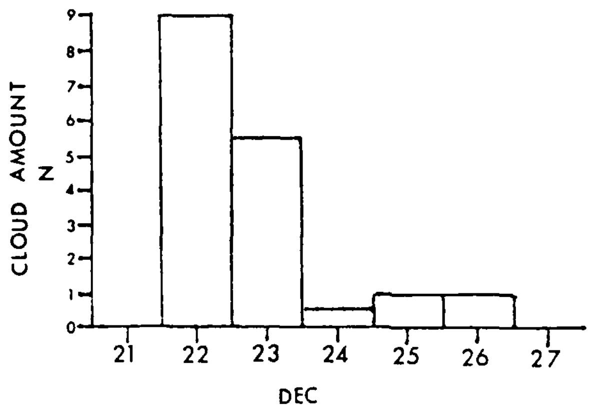

Figure E6. 22-26 December 1981.

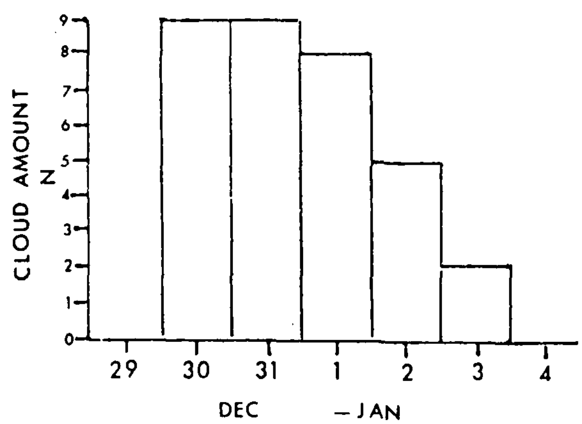

Figure E7. 30 December 1981-3 January 1982.

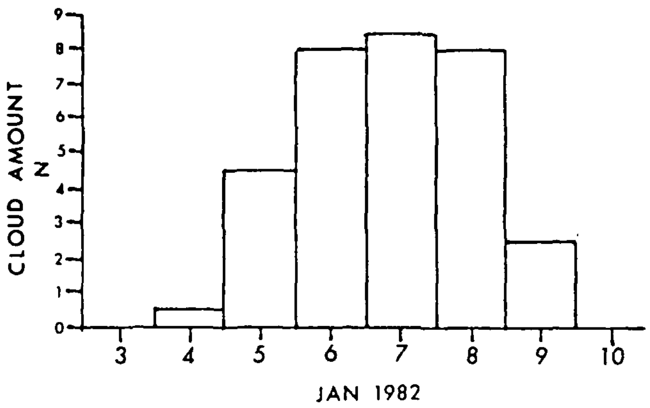

Figure E8. 4-9 January 1982.

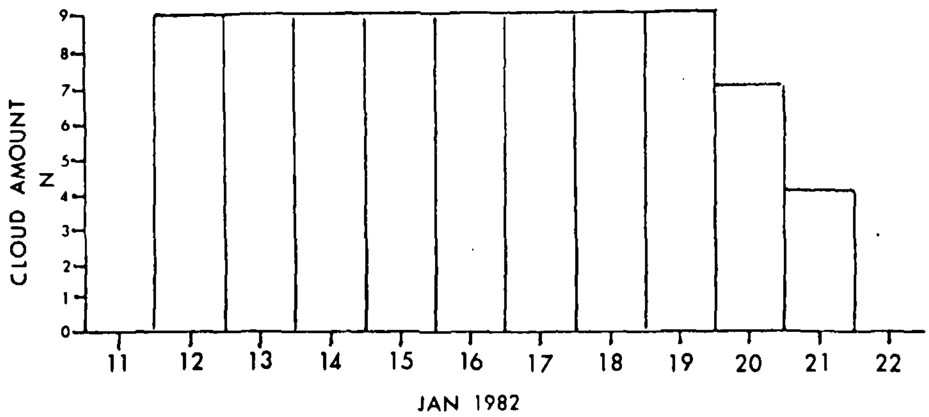

Figure E9. 12-21 January 1982.

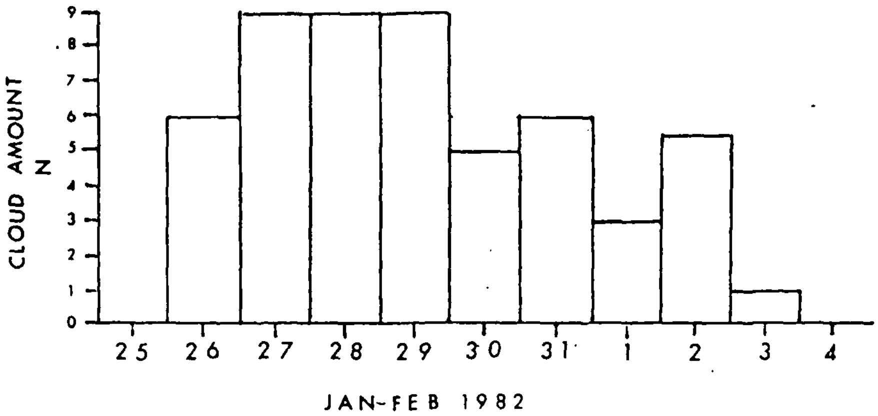

Figure E10. 25 January-3 February 1982.

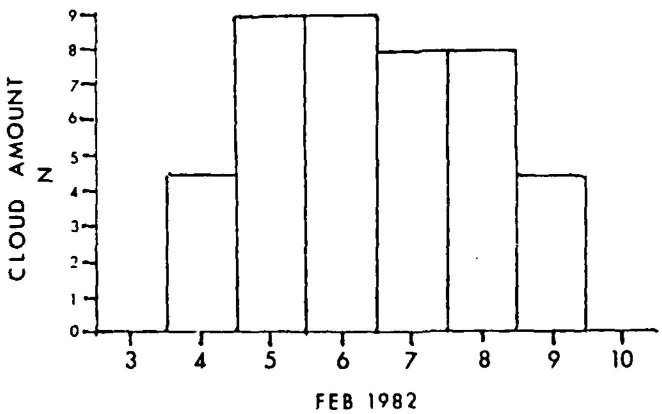

Figure E11. 4-9 February 1982.

APPENDIX F

DESCRIPTION OF COMPUTER PROGRAM KORANL

F.1 An outline of the information flow and computer operations within KORANL (Korean Analysis)

Input:

I. Valid times

II. Vertical velocity

Read:

I. Sea surface temperature (SST) at the point where the air column first moves over water.

II. Initial surface temperature in the air column.

III. Hourly change in SST along the trajectory.

IV. Mixing ratio corresponding to SST at the point where the air column first moves over water.

V. Initial surface mixing ratio in the air column.

VI. Hourly change in mixing ratio corresponding to the change in SST along the trajectory.

VII. Initial 850 mb temperature in the air column.

VIII. Initial 850 mb mixing ratio in the air column.

IX. Initial 850 mb height.

X. Time that the air column will be over land before moving over water.

XI. Total time of travel from the initial point to the terminal point.

XII. 850 mb geostrophic wind speed.

XIII. Surface pressure.

Print:

I. Valid times

II. Vertical velocity

III. Initial conditions

Compute:

I. For an air parcel in the mixed layer by time increments of 1 hour:

A. Temperature change due to sensible heating.

B. Change in mixing ratio due to surface flux of water vapor.

C. Temperature change due to entrainment.

D. Change in mixing ratio due to entrainment.

E. Temperature change due to latent heating.

F. Temperature change due to solar heating and longwave radiative energy exchanges.

G. Temperature change due to adiabatic motion.

II. General:

A. Amount of water vapor condensed in forming or maintaining clouds.

B. Amount of water precipitated if the 850 mb relative humidity is greater than 100%.

C. Growth of the boundary layer.

D. Change in SST.

E. Change in mixing ratio corresponding to change in SST.

III. New conditions in the air column:

A. 850 mb temperature.

B. 850 mb mixing ratio.

C. Surface temperature.

D. Surface mixing ratio.

E. Boundary layer stability parameter.

F. 850 mb relative humidity.

G. Depth of the boundary layer.

Print:

I. For increments of 1 hour:

A. Temperature change due to sensible heating.

B. Sea surface temperature.

C. Surface air temperature.

D. 850 mb temperature.

E. 850 mb relative humidity.

F. Temperature change due to radiative cooling and solar heating.

G. Change in mixing ratio due to surface flux of water vapor.

H. Temperature change due to latent heating.

I. Boundary layer stability parameter.

II. For final time step:

A. Change in temperature due to entrainment.

B. Change in mixing ratio due to entrainment.

III. Total changes:

A. Change in temperature due to sensible heating.

B. Change in temperature due to solar heating and longwave radiative energy exchanges.

C. Change in temperature due to latent heating.

D. Change in temperature due to entrainment.

E. Change in mixing ratio due to entrainment.

F. Total change in mixing ratio.

<u>Compute</u>:

I. Cloud amount from stability parameter.

II. Expected error from 850 mb relative humidity.

III. Final cloud amount.

<u>Print</u>:

I. Depth of the boundary layer.

II. Snow amount.

III. Cloud amount.

F.2 Description of parameters input to KORANL

The following data are necessary to forecast the amount of cold air stratocumulus with the program KORANL:

1. Line 30 - Surface parameters:

TS --- Sea surface temperature at the point where the air column first moves over water.

TA --- Surface temperature in the air column at the initial point.

DTS -- Hourly change in sea surface temperature along the trajectory (determined from climatology and length of time the air column is expected to be over water).

QS --- Mixing ratio corresponding to the sea surface temperature at the point where air column first moves over water.

QA --- Surface mixing ratio at the initial point.

DQS -- Hourly change in mixing ratio corresponding to the change in sea surface temperature along the trajectory.

2. Line 50 - 850 mb parameters:

   T8 --- 850 mb temperature at the initial point.

   Q8 --- 850 mb mixing ratio at the initial point.

   Z8 --- 850 mb height at the initial point.

3. Line 70 - Other parameters:

   TO --- Time in hours that the air column will be over land.

   T ---- Total time of travel from the initial point to the terminal point.

   U ---- 850 mb geostrophic wind speed (calculated from the 850 mb analysis).

   P ---- Surface pressure at the initial point.

4. Vertical velocity:

   KORANL prompts the user to input the vertical velocity by a printed message. If the user does not input a vertical velocity, the program uses a value of 0.0 cm/s.

5. Comments:

   The forecast trajectory of the air column is constructed from the 850 mb analysis. The user estimates the average 850 mb wind speed upstream from the terminal point (36°N, 125°E) by calculating the geostrophic wind speed in natural coordinates. The trajectory is based on continuity of major synoptic features. It is assumed that the column of air moves as a unit and that the speed of movement is that of the 850 mb geostrophic wind.

F.3 Description of output parameters from KORANL

The following parameters are included in the printed output from KORANL:

TIME --- Time since the air column left the initial point.

SH ----- Hourly temperature change due to sensible heating.

TS ----- Sea surface temperature.

TA ----- Surface temperature in the air column.

T8 ----- 850 mb temperature in the air column.

RT ----- Hourly temperature change due to radiative energy exchanges.

DQ ----- Hourly change in mixing ratio in the air column.

LH ----- Hourly temperature change due to latent heating.

GAMMA -- Boundary layer stability parameter.

TE ----- Hourly change in temperature due to entrainment.

QE ----- Hourly change in mixing ratio due to entrainment.

SENS. -- Total change in temperature due to sensible heating.

RAD. --- Total change in temperature due to radiation.

LAT. --- Total change in temperature due to latent heating.

Q.ENT. - Total change in mixing ratio due to entrainment.

Q.TOT. - Total change in mixing ratio.

F.4 Comparison of KORANL results to observations

Besides the cloud forecast verification, the accuracy of KORANL output was checked against observations of 850 mb temperature and the boundary layer stability parameter (Table F-1). The results of this comparison show that the Lagrangian model's error is within a tolerable range, considering the mean error in upper air soundings is on the order of 1°C. The absolute error in 850 mb temperature from KORANL is 1.2°C while the absolute error in [illegible] is 0.7. An

Table F-1. Comparison of 850 mb temperature and boundary layer stability parameter predicted by KORANL to observations based on upper air analyses.

*Valid Time	Predicted Temperature	Observed Temperature	Predicted Stability Parameter	Observed Stability Parameter
17 Nov 81/0000Z	-6.2	-3.5	13.3	11.0
21 Nov 82/0000Z	-1.8	-1.5	9.6	9.2
21 Nov 81/1200Z	-0.1	1.0	8.8	7.5
2 Dec 81/0000Z	-7.7	-8.4	12.4	12.6
9 Dec 81/0000Z	-3.7	-2.0	9.2	7.9
10 Dec 81/0000Z	-1.0	-1.5	7.3	7.5
17 Dec 81/0000Z	-6.1	-4.5	9.3	8.7
20 Dec 81/0000Z	-2.3	-3.5	7.2	8.6
24 Dec 81/0000Z	-4.6	-5.0	9.2	9.3
9 Dec 81/1200Z	-3.0	-2.0	8.7	7.9
19 Dec 81/1200Z	-7.3	-9.5	11.4	12.8
29 Dec 81/1200Z	-6.4	-7.5	10.4	10.9
11 Jan 82/0000Z	2.9	0.0	3.3	5.4
21 Jan 82/0000Z	-0.2	-2.0	6.3	6.2
1 Feb 82/0000Z	-9.7	-9.0	11.5	10.9
5 Feb 82/0000Z	-11.1	-9.0	12.3	10.9
6 Feb 82/0000Z	-10.6	-11.5	12.2	12.7
7 Feb 82/0000Z	-12.5	-12.5	13.3	13.1
15 Feb 82/0000Z	-4.7	-4.5	7.2	7.5
24 Feb 82/1200Z	-6.0	-5.0	8.3	7.8

*Valid at 36°N, 125°E.

error of this magnitude gives an error of about 1.5 in cloud amount.

F.5 Program listing and sample output

KORANL is written in Extended Color Basic 1.0 language for a TRS-80 Color Computer. This section contains a copy of the computer program.

```
10 'KOPANL
20 REM DATA TS,TA,DTS,QS,QZ,DQS
30 DATA 5.5,-5,.108,5.7,.6,.042
40 REM DATA T8,Q8,Z8
50 DATA -12.5,.9,1.45
60 REM DATA T0,T,U,P
70 DATA 0,12,18.9,1015
75 'PO AND PX ARE THE RELATIVE WEIGHTS IN 10THS OF THE CLEAR AND CLOUDY AREA, RE
SPECTIVELY'
80 PO=0.3
90 PX=0.7
100 PRINT STRING$(32,"-")
110 PRINT"TYPE 1 AND HIT RETURN FOR OUTPUT IN SHORT FORMAT; HIT RETURN FOR OUTPU
T IN LONG FORMAT"
120 PRINT STRING$(32,"-")
130 INPUT"OUTPUT OPTION";PF
140 'DATA INPUT LINES BEGIN WITH 20
150 'ATMOSPHERIC APPLICATIONS -- 14 JAN 84'
160 'INCLUDES OPTIONS FOR VERTICAL MOTION AND ENTRAINMENT
170 '2-LAYER LAGRANGIAN MODEL
180 "MODIFICATION OF CP AIR TO MP AIR - ASIAN WINTER MONSOON
185 'USES STATISTICAL-DYNAMICAL METHOD TO FORECAST COLD AIR STRATOCUMULUS
190 DIM H(24),Q(24)
200 PRINT STRING$(32,"-")
210 LINE INPUT "VALID:";VT$
220 PRINT STRING$(32,"-")
230 PRINT#-2,TAB(13)"VALID:";VT$
240 'OPTIONS FOR VERTICAL MOTION AND ENTRAINMENT
250 LINE INPUT "TYPE YES AND HIT RETURN IF YOU WANT TO INPUT VERTICAL VELOCITY;
HIT RETURN IF YOU WANT VERTICAL VELOCITY TO BE O CM/S----";VM$
260 PRINT STRING$(32,"-")
270 IF VM$="YES" THEN 290
280 GOTO 310
290 INPUT "VERTICAL VELOCITY";WW
300 PRINT STRING$(32,"-")
310 EN$="YES"
320 'INPUT VARIABLES
325 'ALL TEMPERATURES ARE IN DEGREES-CELSIUS
330 'TS=SEA SURFACE TEMP AT FIRST POINT OVER WATER
340 'TA=SFC TEMP IN THE COLUMN
350 'DTS=HOURLY CHANGE IN SEA SFC TEMP
360 'QS=MIXING RATIO CORRESPONDING TO SEA TEMP
370 'QA=SFC MIXING RATIO IN COLUMN
380 'DQS=HOURLY CHANGE IN SEA SFC MIXING RATIO
390 READ TS,TA,DTS,QS,QA,DQS
400 READ T8,Q8,Z8
410 'T8=850MB TEMP
420 'Q8=850MB MIXING RATIO
430 'Z8=850MB HEIGHT IN KM
440 READ T0,T,U,P
445 'T0=TIME COLUMN IS OVER LAND
450 'T=TOTAL LENGTH OF TIME
```

```
460 'U=MEAN WIND SPEED OF THE FBL IN M/S
465 'P=SFC PRESSURE IN MB
470 'ASSUME U IS APPROXIMATELY EQUAL 850MB GEOSTROPHIC WIND
480 PRINT#-2,TAB(13)"--INITIAL CONDITIONS--"
490 PRINT#-2,TAB(15)"TS    TA     DTS    QS  QA   DQS    T8   Q8   Z8    U"
500 PRINT#-2,USING"                  ##.# ###.#   #.###   #.# #.#  #.### ###.# #.# #
.### ##.#";TS;TA;DTS;QS;QA;DQS;T8;Q8;Z8;U
510 PRINT#-2,TAB(13)"VERTICAL VELOCITY OF AIR PARCEL = "WW" CM/S"
520 PRINT#-2,TAB(13)"--RESULTS--"
530 'THE JUMP IN MIXING RATIO AND TEMPERATURE ACROSS THE INVERSION ARE
540 'FQ AND FT, RESPECTIVELY
550 'THE MODEL ASSUMES THAT FQ=0.25 G/KG AND FT=1.0 DEG K
560 'DIFFERENT VALUES OF FQ AND FT MAY BE ENTERED IF UPPER AIR
570 'SOUNDINGS ARE AVAILABLE
580 'THE NEW VALUES MAY BE ENTERED BY CHANGING FQ AND FT IN THE
590 'FOLLOWING STATEMENTS
600 FQ=0.25:QF=Q8-0.25
610 FT=1.0:TF=T8+FT
620 'COMPUTE CHANGE IN TEMPERATURE AND MIXING RATIO
630 'THE TENDENCY EQUATIONS ARE SOLVED BY USING THE EULER METHOD
640 'LINEARITY IS ASSUMED
650 DB=Z8
660 FOR I=1 TO T
670 IF I = < T0 THEN 770
680 GAMMA=(TS-T8)/Z8
690 GOSUB 1810
700 H(I)=(TS-TA)*U*6.885E-3/DB
710 'COMPUTE THE CHANGE IN SEA TEMP FOR NEXT TIME STEP
720 TS=TS+DTS
730 Q(I)=(QS-QA)*U*6.885E-3/DB
740 'COMPUTE THE CHANGE IN MIXING RATIO CORRESPONDING TO SEA TEM
750 'FOR NEXT TIME STEP
760 QS=QS+DQS
770 'COMPUTE SATURATION VAPOR PRESSURE FOR 850MB
780 ES=6.11*EXP(5.4171E+3*(1/273.15-1/(T8+273.15)))
790 'COMPUTE SATURATION MIXING RATIO FOR 850MB
800 QM8=0.622*ES/(850-ES)
810 'COMPUTE RELATIVE HUMIDITY FOR 850MB
820 RH=Q8*0.001/QM8*100
830 'COMPUTE G OF WATER CONDENSED
840 IF EN$="YES" THEN GOSUB 1630
850 C1=C1+1
860 IF C1=1 THEN 880
870 GOTO 910
880 IF RH = > 80 THEN LQ=Q8
890 GOTO 960
900 IF F1=1 THEN 960
910 IF RH < 80 THEN 1070
920 IF F1=1 THEN 960
930 GOSUB 1930
940 LQ=800*QM8
950 F1=1
960 GOSUB 1930
970 GW=Q8-LQ
980 LQ=Q8
990 IF RH = > 100 THEN 1010
1000 GOTO 1050
```

```
1010 PO=Q8-QM8*1000
1020 Q8=QM8*1000
1030 LQ=Q8
1040 PW=PW+PO
1050 'COMPUTE CHANGE IN TEMP DUE TO LATENT HEAT RELEASE DURING CONDENSATION
1060 LH=2500*GW*CT/(1005*DB*1000)
1070 'COMPUTE CHANGE IN TEMP DUE TO LONGWAVE RADIATIVE ENERGY EXCHANGE
1080 E8=Q8*0.001*850/0.622
1090 EA=QA*0.001*PA/0.622
1100 IF RH = > 80 AND RH < 85 THEN TB=T8+275.15
1110 IF RH = > 85 AND RH < 90 THEN TB=T8+277.15
1120 IF RH = > 90 THEN TB=T8+279.15
1130 IF RH < 80 THEN RT=-0.0375
1140 IF RH < 80 THEN 1180
1150 FX=0.817E-10*(-TB^4+(T8+273.15)^4*(-0.35)+(TA+273.15)^4)
1160 RX=FX*4.186E+4*60/((1.003E+3)*(1.0+0.84*QM8)*DB*1000)
1170 RT=RX*RX-PO*0.05+0.0125
1180 IF VM$="NO" THEN 1250
1190 'COMPUTE CHANGE IN TEMP DUE TO VERTICAL MOTION
1200 'CHANGE IS FOR PARCEL WHICH WILL BE AT 850MB AT ECP
1210 DZ=TA-T8
1220 LAPSE=DZ/(Z8*1000)
1230 DLT=WW*36*(.01-LAPSE)
1240 'COMPUTE CHANGE IN TEMP
1250 T8=T8+H(I)+LH+RT-DLT+TE
1260 TA=TA+H(I)+LH+RT-DLT+TE
1270 GOSUB 2010
1280 'COMPUTE LAPSE RATE
1290 GAMMA=(TS-T8)/Z8
1300 'COMPUTE CHANGE IN MIXING RATIO
1310 Q8=Q8+Q(I)+QE
1320 QA=QA+Q(I)+QE
1330 IF PF=1 THEN 1360
1340 IF I=1 THEN 1380
1350 IF I > 1 THEN 1390
1360 IF I=T THEN 1380
1370 GOTO 1500
1380 PRINT#-2,TAB(13)"TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA"
1390 PRINT#-2,USING"                ##  #.## ###.# ###.# ###.# ##.## ###.# #.## #.
###  ##.##";I;H(I);TS;TA;T8;RT;RH;Q(I);LH;GAMMA
1400 IF I=T THEN 1420
1410 GOTO 1500
1420 PRINT#-2,TAB(15)"TE    QE"
1430 PRINT#-2,USING"              ##.### ##.###";TE;QE
1440 PRINT#-2,TAB(13)"SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT."
1450 PRINT#-2,USING"             ###.# ###.#   ###.#   ##.###  ##.###  ##.##";HS;
TR;HL;ET;EQ;QD
1460 PRINT#-2,"             AIR COLUMN WAS OVER WATER "T-T0" HOURS"
1470 PRINT#-2,USING"              DEPTH OF PBL = #.### KM";DB
1480 PRINT#-2,USING"              PRECIP WATER = ##.# GRAMS";PW
1490 PRINT#-2,USING"              SNOWFALL = ###.# CM";PW*10
1500 NEXT I
1510 'FORECAST CLOUD AMOUNT
1520 'REGRESSION EQUATIONS FOR N FROM GAMMA AND STEPWISE REDUCTION FOR RH
1530 NG=(GAMMA-7.307)/.4533
1540 NR=(RH-78.395)/3.154
1550 IF NG < 0 THEN NG=0
```

```
1560 IF NG > 9 THEN NG=9
1570 N=NG+NR
1580 IF N > 9 THEN N=9
1590 IF N < 0 THEN N=0
1600 PRINT#-2,USING"            CLOUD AMOUNT = #.#";N
1610 PRINT#-2:PRINT#-2
1620 END
1630 'SUBROUTINE -- ENTRAINMENT
1640 IF GAMMA = < 9 THEN 1660
1650 GOTO 1690
1660 IF RH = > 80 THEN WE=0.8
1670 IF RH < 80 THEN WE=0.1
1680 GOTO 1760
1690 IF GAMMA > 9 AND GAMMA < = 11 THEN 1710
1700 GOTO 1740
1710 IF RH = > 80 THEN WE=2.0
1720 IF RH < 80 THEN WE=1.0
1730 GOTO 1760
1740 IF RH = > 80 THEN WE=4.0
1750 IF RH < 80 THEN WE=2.0
1760 QJ=0E-08
1770 QE=WE*QJ*3600/(DB*1E+5)
1780 TJ=0.5
1790 TE=WE*TJ*3600/(DB*1E+5)
1800 RETURN
1810 'SUBROUTINE -- GROWTH OF THE BOUNDARY LAYER'
1820 IF GAMMA > 8 AND GAMMA < = 9 THEN 1840
1830 GOTO 1860
1840 ZG=0.005
1850 GOTO 1910
1860 IF GAMMA > 9 AND GAMMA < = 10 THEN 1880
1870 GOTO 1900
1880 ZG=0.0075
1890 GOTO 1910
1900 IF GAMMA > 10 THEN ZG=0.010
1910 DB=DB+ZG
1920 RETURN
1930 'SUBROUTINE -- CLOUD LAYER THICKNESS'
1940 IF RH = > 80 AND RH < 85 THEN CT=304.8
1950 IF RH = > 85 AND RH < 90 THEN CT=609.6
1960 IF RH = > 90 AND RH < 100 THEN CT=914.4
1970 IF RH = > 100 THEN 1990
1980 RETURN
1990 CT=CT+ZG
2000 RETURN
2010 'SUBROUTINE -- TOTAL HEATING AND MOISTURE CHANGE
2020 TR=TR+RT
2030 HS=HS+H(I)
2040 HL=HL+LH
2050 QD=QD+Q(I)
2060 ET=ET+TE
2070 EQ=EQ+QE
2080 RETURN
```

F.6 Sensitivity of numerical results to approximations and assumptions

For most processes, the model contains assumptions or approximations supported by available data, theory, and/or the results of other studies. Due to the effects scale, some of these processes are less significant than others. Although some processes cause relatively small changes in the boundary layer compared to the surface fluxes, it is felt that even a crude approximation for these is better than neglecting them completely. This section contains the results of sensitivity testing of the numerical results to the approximations regarding cloud layer thickness, boundary layer growth, entrainment rate, solar heating, radiative cooling, and vertical velocity. It is found that the 850 mb relative humidity is highly sensitive to the entrainment rate and that the 850 mb temperature is highly sensitive to vertical velocity. Otherwise, the impact on the numerical results is small.

F.6.1 Cloud layer thickness

The model approximates cloud layer thickness from the 850 mb relative humidity. The thickness of the layer increases as the relative humidity increases. Additional growth of the layer occurs if there is precipitation. The values used in the model are:

a. 300 m if $80\% \leq RH \leq 85\%$

b. 600 m if $85\% < RH \leq 90\%$

c. 900 m if $RH > 90\%$

d. If RH $\geq$ 100% the cloud layer thickness increases at the same rate as that of the height of the boundary layer.

The sensitivity of the numerical results is tested by varying the model values. Cases are presented in which the thickness is uniformly increased and decreased by 200 m. Another case assuming a thickness of 1200 m for all RH 80% is included. These changes produce relatively small variations in the 850 mb temperature (.1 - .4°C) and in relative humidity (1.2 - 2.3%).

SENSITIVITY TESTING - CLOUD LAYER THICKNESS
THIS CASE USES THE SAME VALUES AS IN
MODEL VERIFICATION

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.017	13.95
5	0.48	4.9	-6.6	-15.6	-0.11	87.1	0.16	0.098	13.83
6	0.47	5.2	-6.1	-15.1	-0.13	90.0	0.16	0.134	13.70
7	0.46	5.5	-5.6	-14.6	-0.13	92.0	0.17	0.123	13.59
8	0.45	5.9	-5.1	-14.1	-0.13	93.3	0.17	0.114	13.48
9	0.45	6.2	-4.6	-13.6	-0.13	94.3	0.17	0.106	13.39
10	0.44	6.5	-4.2	-13.2	-0.13	94.8	0.17	0.099	13.31
11	0.44	6.9	-3.7	-12.7	-0.13	95.1	0.18	0.094	13.23
12	0.43	7.2	-3.3	-12.3	-0.14	95.2	0.18	0.089	13.16

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.3	0.9	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - CLOUD LAYER THICKNESS
THIS CASES SUBTRACTS 200 M FROM THE VALUES USED
IN MODEL VERIFICATION

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.006	13.96
5	0.48	4.9	-6.6	-15.6	-0.11	87.2	0.16	0.066	13.86
6	0.47	5.2	-6.2	-15.2	-0.13	90.3	0.16	0.105	13.75
7	0.46	5.5	-5.7	-14.7	-0.13	92.5	0.17	0.096	13.65
8	0.46	5.9	-5.2	-14.2	-0.13	94.1	0.17	0.089	13.56
9	0.45	6.2	-4.8	-13.8	-0.13	95.2	0.17	0.083	13.48
10	0.45	6.5	-4.3	-13.3	-0.13	95.9	0.17	0.078	13.41
11	0.44	6.9	-3.9	-12.9	-0.13	96.3	0.18	0.073	13.34
12	0.44	7.2	-3.5	-12.5	-0.14	96.4	0.18	0.069	13.28

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.3	0.7	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - CLOUD LAYER THICKNESS
THIS CASE ADDS 200 M TO THE VALUES USED IN VERIFICATION

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.028	13.94
5	0.48	4.9	-6.6	-15.6	-0.11	87.0	0.16	0.130	13.80
6	0.47	5.2	-6.0	-15.0	-0.12	89.7	0.16	0.119	13.68
7	0.46	5.5	-5.5	-14.5	-0.13	91.7	0.17	0.150	13.54
8	0.45	5.9	-5.0	-14.0	-0.13	92.9	0.17	0.139	13.43
9	0.44	6.2	-4.5	-13.5	-0.13	93.6	0.17	0.130	13.32
10	0.44	6.5	-4.0	-13.0	-0.13	94.0	0.17	0.121	13.22
11	0.43	6.9	-3.6	-12.6	-0.14	94.2	0.18	0.114	13.14
12	0.43	7.2	-3.1	-12.1	-0.14	94.1	0.18	0.108	13.06

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.2	1.0	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - CLOUD LAYER THICKNESS
THIS CASE ASSUMES A CLOUD THICKNESS OF 1200 M

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.068	13.92
5	0.47	4.9	-6.5	-15.5	-0.11	86.7	0.16	0.192	13.73
6	0.46	5.2	-5.9	-14.9	-0.12	89.0	0.16	0.176	13.57
7	0.45	5.5	-5.4	-14.4	-0.13	90.5	0.17	0.162	13.44
8	0.45	5.9	-4.8	-13.8	-0.13	91.7	0.17	0.150	13.32
9	0.44	6.2	-4.4	-13.4	-0.13	92.4	0.17	0.140	13.21
10	0.43	6.5	-3.9	-12.9	-0.13	92.8	0.17	0.131	13.11
11	0.43	6.9	-3.4	-12.4	-0.14	92.9	0.18	0.123	13.02
12	0.42	7.2	-3.0	-12.0	-0.14	92.9	0.18	0.116	12.95

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.5	-1.2	1.3	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

F.6.2 Sensitivity of numerical results to growth rate of the boundary layer

The model approximates the growth rate of the boundary layer from γ. The growth rate increases as γ increases. These rates are obtained from upper air soundings. The values used in the model are:

a. 5 m/hr if $8°C/km < \gamma \leq 9°C/km$

b. 7.5 m/hr if $9°C/km < \gamma \leq 10°C/km$

c. 10 m/hr if $\gamma > 10°C/km$

Although actual growth rates may be as large as 50 m/hr, the sensitivity of the numerical results to a rate of this magnitude is fairly small (.7°C variation in 850 mb temperature and .5 change in relative humidity).

SENSITIVITY TESTING - GROWTH OF THE BOUNDARY LAYER
THIS CASE ASSUMES A GROWTH RATE OF 0 M/HR

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.017	13.95
5	0.48	4.9	-6.6	-15.6	-0.11	87.1	0.16	0.098	13.83
6	0.47	5.2	-6.1	-15.1	-0.13	90.0	0.16	0.134	13.70
7	0.46	5.5	-5.6	-14.6	-0.13	92.0	0.17	0.123	13.59
8	0.45	5.9	-5.1	-14.1	-0.13	93.3	0.17	0.114	13.48
9	0.45	6.2	-4.6	-13.6	-0.13	94.3	0.17	0.106	13.39
10	0.44	6.5	-4.2	-13.2	-0.13	94.8	0.17	0.099	13.31
11	0.44	6.9	-3.7	-12.7	-0.13	95.1	0.18	0.094	13.23
12	0.43	7.2	-3.3	-12.3	-0.14	95.2	0.18	0.089	13.16

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.3	0.9	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - GROWTH OF THE BOUNDARY LAYER
THIS CASE ASSUMES A GROWTH RATE OF 10 M/HR

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.2	0.16	0.000	14.13
3	0.48	4.2	-7.6	-16.6	-0.04	74.5	0.16	0.000	14.04
4	0.47	4.5	-7.1	-16.1	-0.10	82.4	0.16	0.015	13.97
5	0.46	4.9	-6.7	-15.7	-0.11	86.8	0.16	0.093	13.86
6	0.45	5.2	-6.2	-15.2	-0.11	89.7	0.16	0.084	13.77
7	0.44	5.5	-5.7	-14.7	-0.12	91.9	0.16	0.115	13.67
8	0.44	5.9	-5.2	-14.2	-0.12	93.4	0.16	0.106	13.58
9	0.43	6.2	-4.8	-13.8	-0.13	94.4	0.16	0.098	13.51
10	0.42	6.5	-4.4	-13.4	-0.13	95.1	0.16	0.091	13.44
11	0.41	6.9	-3.9	-12.9	-0.13	95.5	0.16	0.085	13.38
12	0.41	7.2	-3.5	-12.5	-0.13	95.7	0.17	0.080	13.33

TE	QE
0.045	-0.112

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.4	-1.2	0.8	0.488	-0.875	1.93

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.600 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - GROWTH OF THE BOUNDARY LAYER
THIS CASE ASSUMES A GROWTH RATE OF 50 M/HR

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.48	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.23
2	0.46	3.9	-8.1	-17.1	-0.04	65.0	0.15	0.000	14.15
3	0.44	4.2	-7.7	-16.7	-0.04	73.9	0.15	0.000	14.09
4	0.43	4.5	-7.3	-16.3	-0.09	81.3	0.14	0.007	14.05
5	0.41	4.9	-6.8	-15.8	-0.10	85.6	0.14	0.076	13.98
6	0.40	5.2	-6.4	-15.4	-0.10	88.5	0.14	0.067	13.93
7	0.38	5.5	-6.0	-15.0	-0.11	90.8	0.14	0.089	13.88
8	0.37	5.9	-5.6	-14.6	-0.10	92.5	0.13	0.080	13.85
9	0.36	6.2	-5.3	-14.3	-0.10	93.8	0.13	0.072	13.82
10	0.35	6.5	-4.9	-13.9	-0.10	94.9	0.13	0.065	13.81
11	0.34	6.9	-4.6	-13.6	-0.10	95.6	0.13	0.060	13.81
12	0.33	7.2	-4.2	-13.2	-0.10	96.2	0.13	0.055	13.81

TE	QE
0.035	-0.082

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
4.8	-1.0	0.6	0.415	-0.697	1.67

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 2.080 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

F.6.3 Entrainment rate

The model approximates entrainment rate from γ and RH as shown in Figure 8. The rates vary from 0.2 to 4.0 cm/s. These values are comparable to those presented by Deardorff (1976). The sensitivity of the numerical results is tested by uniformly doubling the model rates. It is found that the 850 mb relative humidity is highly sensitive to entrainment rate (reduced from 95.2% to 77.6%). The change in 850 mb temperature is just .1°C. It is important to note that the values used in the model produce point forecasts of clouds that agree well with the satellite imagery.

SENSITIVITY TESTING - ENTRAINMENT RATE
THIS CASE HAS THE SAME RATES USED IN VERIFICATION

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.017	13.95
5	0.48	4.9	-6.6	-15.6	-0.11	87.1	0.16	0.098	13.83
6	0.47	5.2	-6.1	-15.1	-0.13	90.0	0.16	0.134	13.70
7	0.46	5.5	-5.6	-14.6	-0.13	92.0	0.17	0.123	13.59
8	0.45	5.9	-5.1	-14.1	-0.13	93.3	0.17	0.114	13.48
9	0.45	6.2	-4.6	-13.6	-0.13	94.3	0.17	0.106	13.39
10	0.44	6.5	-4.2	-13.2	-0.13	94.8	0.17	0.099	13.31
11	0.44	6.9	-3.7	-12.7	-0.13	95.1	0.18	0.094	13.23
12	0.43	7.2	-3.3	-12.3	-0.14	95.2	0.18	0.089	13.16

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.3	0.9	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

AD-A141 540 A STATISTICAL-DYNAMICAL MODEL FOR FORECASTING COLD AIR STRATOCUMULUS OVER THE YELLOW SEA(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH H L MASSIE MAY 84 3/3

UNCLASSIFIED AFIT/CI/NR-84-12T F/G 4/2 NL

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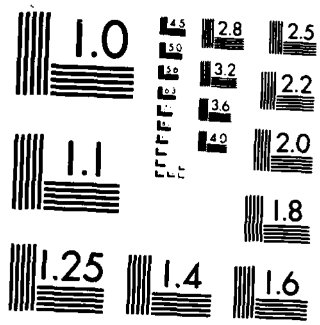

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SENSITIVITY TEST - ENTRAINMENT RATE
THIS CASE ASSUMES ALL RATES ARE DOUBLE THE VALUES
USED IN THE MODEL VERIFICATION

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.20
2	0.49	3.9	-8.0	-17.0	-0.04	64.1	0.16	0.000	14.09
3	0.49	4.2	-7.5	-16.5	-0.04	71.9	0.16	0.000	13.98
4	0.48	4.5	-7.0	-16.0	-0.04	78.0	0.16	0.000	13.87
5	0.47	4.9	-6.5	-15.5	-0.10	82.8	0.16	0.019	13.77
6	0.47	5.2	-6.0	-15.0	-0.10	81.2	0.17	0.011	13.67
7	0.46	5.5	-5.6	-14.6	-0.04	79.7	0.17	0.011	13.57
8	0.45	5.9	-5.0	-14.0	-0.10	83.3	0.17	0.061	13.45
9	0.45	6.2	-4.6	-13.6	-0.10	80.2	0.18	0.002	13.38
10	0.44	6.5	-4.2	-13.2	-0.04	78.0	0.18	0.002	13.30
11	0.44	6.9	-3.7	-12.7	-0.11	81.1	0.18	0.054	13.20
12	0.43	7.2	-3.2	-12.2	-0.04	77.6	0.19	0.054	13.09

TE	QE
0.049	-0.095

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-0.8	0.2	0.827	-1.250	2.07

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 8.8

F.6.4 Solar heating

The model assumes uniform heating of 0.3°C per day due to the absorption of solar radiation. This value is based on Charney (1945) who gives an upper limit of 0.6°C per day. The sensitivity of the numerical results is tested by increasing to model values to 0.6 and 1.0°C per day. The results show a maximum increase of 0.3°C per day in 850 mb temperature and a decrease in relative humidity from 95.2% to 93.4%.

SENSITIVITY TESTING - SOLAR HEATING
THIS CASE USES THE SAME VALUE AS IN VERIFICATION

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.017	13.95
5	0.48	4.9	-6.6	-15.6	-0.11	87.1	0.16	0.098	13.83
6	0.47	5.2	-6.1	-15.1	-0.13	90.0	0.16	0.134	13.70
7	0.46	5.5	-5.6	-14.6	-0.13	92.0	0.17	0.123	13.59
8	0.45	5.9	-5.1	-14.1	-0.13	93.3	0.17	0.114	13.48
9	0.45	6.2	-4.6	-13.6	-0.13	94.3	0.17	0.106	13.39
10	0.44	6.5	-4.2	-13.2	-0.13	94.8	0.17	0.099	13.31
11	0.44	6.9	-3.7	-12.7	-0.13	95.1	0.18	0.094	13.23
12	0.43	7.2	-3.3	-12.3	-0.14	95.2	0.18	0.089	13.16

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.3	0.9	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - SOLAR HEATING
THIS CASE ASSUMES SOLAR HEATING OF 0.6 DEG-C

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.09	82.7	0.16	0.017	13.94
5	0.48	4.9	-6.6	-15.6	-0.10	87.0	0.16	0.098	13.81
6	0.47	5.2	-6.1	-15.1	-0.10	89.8	0.16	0.089	13.70
7	0.46	5.5	-5.6	-14.6	-0.12	91.9	0.17	0.123	13.58
8	0.45	5.9	-5.1	-14.1	-0.12	93.2	0.17	0.114	13.46
9	0.45	6.2	-4.6	-13.6	-0.12	94.1	0.17	0.106	13.36
10	0.44	6.5	-4.1	-13.1	-0.12	94.5	0.17	0.099	13.27
11	0.44	6.9	-3.7	-12.7	-0.12	94.7	0.18	0.094	13.19
12	0.43	7.2	-3.2	-12.2	-0.12	94.7	0.18	0.089	13.11

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.1	0.8	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - SOLAR HEATING
THIS CASE ASSUMES SOLAR HEATING OF 1.0 DEG-C

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.01	54.3	0.16	0.000	14.20
2	0.49	3.9	-8.0	-17.0	-0.01	65.1	0.16	0.000	14.08
3	0.48	4.2	-7.5	-16.5	-0.01	74.3	0.16	0.000	13.97
4	0.48	4.5	-7.0	-16.0	-0.07	82.1	0.16	0.014	13.88
5	0.47	4.9	-6.5	-15.5	-0.09	86.3	0.16	0.098	13.74
6	0.46	5.2	-6.0	-15.0	-0.09	89.0	0.16	0.089	13.62
7	0.46	5.5	-5.4	-14.4	-0.10	91.0	0.17	0.123	13.49
8	0.45	5.9	-4.9	-13.9	-0.10	92.2	0.17	0.114	13.37
9	0.44	6.2	-4.4	-13.4	-0.10	93.0	0.17	0.106	13.26
10	0.44	6.5	-4.0	-13.0	-0.11	93.4	0.17	0.099	13.16
11	0.43	6.9	-3.5	-12.5	-0.11	93.5	0.18	0.094	13.07
12	0.42	7.2	-3.0	-12.0	-0.11	93.4	0.18	0.089	12.99

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.5	-0.9	0.8	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

F.6.5 Radiational cooling

The model assumes radiational cooling of the boundary layer under clear sky conditions is 1.0°C per day. This value is based on Charney (1945) who gives a range of 1 to 3°C per day for cooling of the free atmosphere due to longwave radiation. The sensitivity of the numerical results to this estimate is tested by increasing the cooling to 2.5°C per day. The result is a decrease in 850 mb temperature of just 0.2°C per day.

SENSITIVITY TESTING - RADIATIVE COOLING UNDER CLEAR SKIES
THIS CASE USES THE SAME VALUE AS IN VERIFICATION

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.5	-17.5	-0.04	54.3	0.16	0.000	14.22
2	0.49	3.9	-8.0	-17.0	-0.04	65.3	0.16	0.000	14.12
3	0.49	4.2	-7.6	-16.6	-0.04	74.7	0.16	0.000	14.03
4	0.48	4.5	-7.1	-16.1	-0.10	82.7	0.16	0.017	13.95
5	0.48	4.9	-6.6	-15.6	-0.11	87.1	0.16	0.098	13.83
6	0.47	5.2	-6.1	-15.1	-0.13	90.0	0.16	0.134	13.70
7	0.46	5.5	-5.6	-14.6	-0.13	92.0	0.17	0.123	13.59
8	0.45	5.9	-5.1	-14.1	-0.13	93.3	0.17	0.114	13.48
9	0.45	6.2	-4.6	-13.6	-0.13	94.3	0.17	0.106	13.39
10	0.44	6.5	-4.2	-13.2	-0.13	94.8	0.17	0.099	13.31
11	0.44	6.9	-3.7	-12.7	-0.13	95.1	0.18	0.094	13.23
12	0.43	7.2	-3.3	-12.3	-0.14	95.2	0.18	0.089	13.16

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.6	-1.3	0.9	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

SENSITIVITY TESTING - RADIATIVE COOLING UNDER CLEAR SKIES
THIS CASE ASSUMES COOLING OF 2.5 DEG-C PER DA

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.2	-9.0	0.333	4.7	0.7	0.125	-18.0	0.6	1.480	8.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.50	3.5	-8.6	-17.6	-0.09	54.3	0.16	0.000	14.25
2	0.50	3.9	-8.1	-17.1	-0.09	65.6	0.16	0.000	14.19
3	0.49	4.2	-7.7	-16.7	-0.09	75.3	0.16	0.000	14.12
4	0.49	4.5	-7.3	-16.3	-0.12	83.7	0.16	0.023	14.05
5	0.48	4.9	-6.8	-15.8	-0.13	88.1	0.16	0.098	13.94
6	0.48	5.2	-6.2	-15.2	-0.14	91.2	0.16	0.134	13.81
7	0.47	5.5	-5.8	-14.8	-0.15	93.2	0.17	0.123	13.70
8	0.46	5.9	-5.3	-14.3	-0.15	94.7	0.17	0.114	13.61
9	0.46	6.2	-4.8	-13.8	-0.15	95.7	0.17	0.106	13.52
10	0.45	6.5	-4.4	-13.4	-0.15	96.3	0.17	0.099	13.44
11	0.45	6.9	-3.9	-12.9	-0.15	96.6	0.18	0.094	13.37
12	0.44	7.2	-3.5	-12.5	-0.15	96.7	0.18	0.089	13.30

TE	QE
0.049	-0.124

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
5.7	-1.5	0.9	0.511	-0.934	2.01

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.480 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 9.0

F.6.6 Vertical velocity

This study uses vertical velocities determined subjectively by map typing (Appendix A). Each case uses a vertical velocity of 0.0 cm/s unless the large-scale flow favors vertical motion. The sensitivity of the numerical results to vertical velocity is tested for two cases in which vertical motion is favored. These show that the degree of sensitivity depends upon the temperature lapse rate of the boundary layer. In the first case, where the lapse rate is near the dry adiabatic lapse rate, the change in 850 mb temperature is less than 1.0°C. In the second case, where the lapse rate is small, the temperature varies by up to 4.8°C.

SENSITIVITY TESTING -- VERTICAL VELOCITY APPROXIMATION

VALID: 30DEC81/12Z TO 31DEC/00Z

--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
5.6	0.0	0.250	5.7	1.5	0.108	-9.0	0.9	1.470	4.8

VERTICAL VELOCITY OF AIR PARCEL = .5 CM/S

--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.13	5.9	0.0	-9.0	-0.04	39.4	0.09	0.000	10.08
2	0.13	6.1	0.1	-8.9	-0.04	43.2	0.09	0.000	10.23
3	0.13	6.4	0.1	-8.9	-0.04	46.8	0.09	0.000	10.37
4	0.14	6.6	0.1	-8.9	-0.04	50.3	0.09	0.000	10.51
5	0.14	6.9	0.2	-8.8	-0.04	53.6	0.09	0.000	10.65
6	0.14	7.1	0.2	-8.8	-0.04	56.9	0.09	0.000	10.79
7	0.15	7.4	0.3	-8.7	-0.04	60.0	0.09	0.000	10.93
8	0.15	7.6	0.3	-8.7	-0.04	63.0	0.09	0.000	11.06
9	0.15	7.9	0.4	-8.6	-0.04	65.9	0.09	0.000	11.18
10	0.16	8.1	0.5	-8.5	-0.04	67.8	0.09	0.000	11.30
11	0.16	8.4	0.6	-8.4	-0.04	69.6	0.09	0.000	11.42
12	0.16	8.6	0.6	-8.4	-0.04	71.2	0.10	0.000	11.54

TE	QE
0.023	-0.048

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
1.7	-0.5	0.0	0.187	-0.281	1.13

AIR COLUMN WAS OVER WATER 12 HOURS

DEPTH OF PBL = 1.587 KM

SNOWFALL = 0.0 CM

CLOUD AMOUNT = 5.6

```
VALID: 30DEC81/12Z TO 31DEC/00Z
--INITIAL CONDITIONS--
  TS     TA     DTS      QS   QA    DQS     TS    QS    ZS     U
  5.6   0.0   0.250    5.7 1.5  0.108  -9.0 0.9 1.470  4.8
VERTICAL VELOCITY OF AIR PARCEL =  .25  CM/S
--RESULTS--
TIME  SH      TS     TA     TS    RT     RH   DQ   LH    GAMMA
  1  0.13    5.9    0.1   -8.9 -0.04  39.4 0.09 0.000  10.06
  2  0.13    6.1    0.1   -8.9 -0.04  43.0 0.09 0.000  10.18
  3  0.13    6.4    0.2   -8.8 -0.04  46.5 0.09 0.000  10.30
  4  0.13    6.6    0.3   -8.7 -0.04  49.9 0.09 0.000  10.42
  5  0.14    6.9    0.4   -8.6 -0.04  53.1 0.09 0.000  10.54
  6  0.14    7.1    0.4   -8.6 -0.04  56.1 0.09 0.000  10.66
  7  0.14    7.4    0.5   -8.5 -0.04  59.1 0.09 0.000  10.77
  8  0.15    7.6    0.6   -8.4 -0.04  61.9 0.09 0.000  10.88
  9  0.15    7.9    0.7   -8.3 -0.04  64.6 0.09 0.000  10.99
 10  0.15    8.1    0.8   -8.2 -0.04  67.2 0.09 0.000  11.10
 11  0.15    8.4    0.9   -8.1 -0.04  69.7 0.09 0.000  11.20
 12  0.16    8.6    1.0   -8.0 -0.04  71.0 0.09 0.000  11.30
  TE     QE
 0.023 -0.049
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.   Q.TOT.
 1.7  -0.5     0.0    0.164  -0.243   1.13
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.587 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.0
```

VALID: 30DEC81/12Z TO 31DEC/00Z

--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
5.6	0.0	0.250	5.7	1.5	0.108	-9.0	0.9	1.470	4.8

VERTICAL VELOCITY OF AIR PARCEL = 1 CM/S

--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.13	5.9	-0.0	-9.0	-0.04	39.4	0.09	0.000	10.13
2	0.13	6.1	-0.1	-9.1	-0.04	43.4	0.09	0.000	10.32
3	0.14	6.4	-0.1	-9.1	-0.04	47.3	0.09	0.000	10.51
4	0.14	6.6	-0.1	-9.1	-0.04	51.1	0.09	0.000	10.70
5	0.15	6.9	-0.1	-9.1	-0.04	54.8	0.09	0.000	10.88
6	0.15	7.1	-0.2	-9.2	-0.04	58.4	0.09	0.000	11.06
7	0.16	7.4	-0.2	-9.2	-0.04	61.9	0.09	0.000	11.23
8	0.16	7.6	-0.2	-9.2	-0.04	64.5	0.09	0.000	11.39
9	0.16	7.9	-0.1	-9.1	-0.04	67.0	0.09	0.000	11.56
10	0.17	8.1	-0.1	-9.1	-0.04	69.3	0.10	0.000	11.72
11	0.17	8.4	-0.1	-9.1	-0.04	71.6	0.10	0.000	11.88
12	0.18	8.6	-0.1	-9.1	-0.04	73.8	0.10	0.000	12.03

TE	QE
0.023	-0.046

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
1.8	-0.5	0.0	0.210	-0.311	1.13

AIR COLUMN WAS OVER WATER 12 HOURS

DEPTH OF PBL = 1.587 KM

SNOWFALL = 0.0 CM

CLOUD AMOUNT = 7.4

VALID: 19DEC81/00Z TO 19DEC/12Z

--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
6.3	-7.0	0.500-	6.0	0.8	0.233	-10.5	0.6	1.455	18.9

VERTICAL VELOCITY OF AIR PARCEL = 1.5 CM/S

--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.00	6.3	-7.4	-10.9	-0.04	29.6	0.00	0.000	11.85
2	0.00	6.3	-7.9	-11.4	-0.04	30.6	0.00	0.000	12.14
3	0.00	6.3	-8.3	-11.8	-0.04	31.0	0.00	0.000	12.43
4	0.00	6.3	-8.7	-12.2	-0.04	31.4	0.00	0.000	12.73
5	0.00	6.3	-9.1	-12.6	-0.04	31.8	0.00	0.000	13.02
6	0.00	6.3	-9.6	-13.1	-0.04	32.3	0.00	0.000	13.31
7	1.41	6.8	-8.6	-12.1	-0.04	32.8	0.47	0.000	12.97
8	1.36	7.3	-7.6	-11.1	-0.04	55.9	0.44	0.000	12.67
9	1.31	7.8	-6.8	-10.3	-0.04	73.2	0.43	0.000	12.41
10	1.27	8.3	-5.9	-9.4	-0.17	86.3	0.41	0.133	12.15
11	1.23	8.8	-4.8	-8.3	-0.18	92.9	0.40	0.411	11.75
12	1.17	9.3	-3.8	-7.3	-0.18	95.3	0.40	0.361	11.41

TE	QE
0.048	-0.185

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
7.7	-0.9	0.9	0.342	-0.636	2.55

AIR COLUMN WAS OVER WATER 6 HOURS

DEPTH OF PBL = 1.515 KM

SNOWFALL = 0.0 CM

CLOUD AMOUNT = 9.0

```
VALID: 19DEC81/00Z TO 19DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  6.3  -7.0   0.500   6.0 0.8  0.233 -10.5 0.6 1.455 18.9
VERTICAL VELOCITY OF AIR PARCEL =  .75  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH   GAMMA
  1  0.00   6.3  -7.2 -10.7 -0.04  29.6 0.00 0.000  11.71
  2  0.00   6.3  -7.5 -11.0 -0.04  30.1 0.00 0.000  11.86
  3  0.00   6.3  -7.7 -11.2 -0.04  30.0 0.00 0.000  12.01
  4  0.00   6.3  -7.9 -11.4 -0.04  29.9 0.00 0.000  12.16
  5  0.00   6.3  -8.1 -11.6 -0.04  29.8 0.00 0.000  12.31
  6  0.00   6.3  -8.3 -11.8 -0.04  29.8 0.00 0.000  12.46
  7  1.30   6.8  -7.2 -10.7 -0.04  29.7 0.47 0.000  12.06
  8  1.24   7.3  -6.2  -9.7 -0.04  50.3 0.44 0.000  11.70
  9  1.19   7.8  -5.3  -8.8 -0.04  65.5 0.43 0.000  11.38
 10  1.14   8.3  -4.3  -7.8 -0.04  76.8 0.41 0.000  11.09
 11  1.09   8.8  -3.4  -6.9 -0.17  85.2 0.40 0.130  10.83
 12  1.05   9.3  -2.5  -6.0 -0.17  88.0 0.40 0.228  10.53
  TE     QE
 0.024 -0.095
SENS.   RAD.    LAT.    T.ENT.   Q.ENT.   Q.TOT.
 7.0  -0.7      0.4     0.294   -0.484    2.54
AIR COLUMN WAS OVER WATER  6  HOURS
DEPTH OF PBL = 1.515 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 8.7
```

```
VALID: 19DEC81/00Z TO 19DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA   DQS     T8    Q8    Z8     U
  6.3  -7.0   0.500    6.0 0.8  0.233 -10.5 0.6 1.455 18.9
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
  1  0.00    6.3  -7.0 -10.5 -0.04  29.6 0.00 0.000  11.57
  2  0.00    6.3  -7.0 -10.5 -0.04  29.6 0.00 0.000  11.58
  3  0.00    6.3  -7.1 -10.6 -0.04  29.0 0.00 0.000  11.59
  4  0.00    6.3  -7.1 -10.6 -0.04  28.5 0.00 0.000  11.60
  5  0.00    6.3  -7.1 -10.6 -0.04  28.0 0.00 0.000  11.61
  6  0.00    6.3  -7.1 -10.6 -0.04  27.5 0.00 0.000  11.62
  7  1.19    6.8  -5.9  -9.4 -0.04  27.0 0.47 0.000  11.15
  8  1.12    7.3  -4.8  -8.3 -0.04  45.3 0.44 0.000  10.73
  9  1.06    7.8  -3.8  -7.3 -0.04  58.7 0.43 0.000  10.36
 10  1.01    8.3  -2.8  -6.3 -0.04  69.5 0.41 0.000  10.03
 11  0.96    8.8  -1.9  -5.4 -0.04  77.7 0.39 0.000   9.73
 12  0.92    9.3  -1.0  -4.5 -0.16  83.9 0.38 0.059   9.50
  TE     QE
 0.024 -0.104
SENS.    RAD.    LAT.    T.ENT.   Q.ENT.   Q.TOT.
 6.3  -0.6      0.1     0.234   -0.307    2.52
AIR COLUMN WAS OVER WATER  6  HOURS
DEPTH OF PBL = 1.512 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.2
```

VALID: 19DEC81/00Z TO 19DEC/12Z

--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
6.3	-7.0	0.500	6.0	0.8	0.233	-10.5	0.6	1.455	18.9

VERTICAL VELOCITY OF AIR PARCEL = 2.5 CM/S

--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.00	6.3	-7.7	-11.2	-0.04	29.6	0.00	0.000	12.04
2	0.00	6.3	-8.4	-11.9	-0.04	31.3	0.00	0.000	12.52
3	0.00	6.3	-9.1	-12.6	-0.04	32.3	0.00	0.000	13.00
4	0.00	6.3	-9.8	-13.3	-0.04	33.5	0.00	0.000	13.48
5	0.00	6.3	-10.5	-14.0	-0.04	34.8	0.00	0.000	13.96
6	0.00	6.3	-11.2	-14.7	-0.04	36.1	0.00	0.000	14.43
7	1.55	6.8	-10.3	-13.8	-0.04	37.5	0.47	0.000	14.19
8	1.51	7.3	-9.5	-13.0	-0.04	64.4	0.44	0.000	13.97
9	1.47	7.8	-8.8	-12.3	-0.16	85.1	0.43	0.086	13.79
10	1.44	8.3	-7.6	-11.1	-0.18	98.3	0.41	0.490	13.36
11	1.38	8.8	-6.7	-10.2	-0.18	104.5	0.41	0.425	13.02
12	1.33	9.3	-5.8	-9.3	-0.18	104.4	0.40	0.373	12.76

TE	QE
0.048	-0.174

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
8.7	-1.0	1.4	0.366	-0.668	2.56

AIR COLUMN WAS OVER WATER 6 HOURS

DEPTH OF PBL = 1.515 KM

SNOWFALL = 1.8 CM

CLOUD AMOUNT = 9.0

APPENDIX G

FORECAST RESULTS

Sections G1-G3 of this appendix list the input parameters and results of the test cases used for model verification. The output appears in bulletin format and includes a summary of the total change in temperature and mixing ratio due to diabatic processes.

12-HOUR FORECAST RESULTS

```
VALID: 16NOV81/12Z TO 17NOV/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
 10.6  -1.0    0.250    7.9 1.6  0.150 -12.0 0.9 1.485  9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA    T8    RT    RH   DQ   LH    GAMMA
 12  0.37  13.6   4.8  -6.2 -0.12  94.5 0.26 0.123  13.34
  TE     QE
 0.045 -0.174
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 5.2  -1.2     1.2    0.486  -1.324   3.10
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.605 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0

VALID: 20NOV81/12Z TO 21NOV/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  8.6   3.0    0.333    7.0 2.0  0.167  -5.0 1.2 1.505 11.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA    T8    RT    RH   DQ   LH    GAMMA
 12  0.31  12.6   6.2  -1.8 -0.14  86.4 0.23 0.120   9.56
  TE     QE
 0.023 -0.107
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.6  -0.8     0.3    0.185  -0.594   2.85
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.595 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 6.1
```

```
VALID: 27NOV81/12Z TO 28NOV/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA   DQS     T8    Q8   Z8     U
 8.8  -6.0   0.300    7.2 1.1  0.160 -15.0 0.7 1.515 14.7
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ    LH   GAMMA
 12  0.57  11.8    3.0  -6.0 -0.14  99.8 0.34 0.206  11.72
  TE    QE
 0.045 -0.204
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 7.7  -1.2      2.2    0.437  -1.304   3.59
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.615 KM
PRECIP WATER =  0.1 GRAMS
SNOWFALL =   1.2 CM
CLOUD AMOUNT = 9.0


VALID: 21NOV81/00Z TO 21NOV/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA   DQS     T8    Q8   Z8     U
 10.0   5.0   0.300    7.7 3.5  0.170  -1.5 2.2 1.495  7.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ    LH   GAMMA
 12  0.20  13.0    6.4  -0.1 -0.04  77.6 0.14 0.000   8.75
  TE    QE
 0.001 -0.003
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.8  -0.5      0.0    0.014  -0.022   1.39
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.530 KM
PRECIP WATER =  0.0 GRAMS
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 1.6


VALID: 1DEC81/12Z TO 2DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA   DQS     T8    Q8   Z8     U
 8.4  -9.0   0.375    7.0 0.8  0.188 -16.3 0.6 1.539 14.7
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ    LH   GAMMA
 12  0.77  11.4   -0.4  -7.7 -0.14 100.3 0.35 0.259  12.39
  TE    QE
 0.044 -0.184
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 7.6  -1.0      1.7    0.389  -0.925   2.97
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.619 KM
PRECIP WATER =  0.1 GRAMS
SNOWFALL =   0.7 CM
CLOUD AMOUNT = 9.0
```

```
VALID: 4DEC81/12Z TO 5DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  7.9    3.0   0.300    6.7 2.4  0.130   -6.0 1.7 1.510  6.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8    RT     RH   DQ    LH   GAMMA
 12  0.18  10.9    4.2  -4.8 -0.11  84.3 0.13 0.935  10.38
  TE    QE
 0.023 -0.054
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.7  -0.7     0.1    0.163  -0.254   1.26
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.592 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 7.2

VALID: 8DEC81/12Z TO 9DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  6.4    3.0   0.444    6.0 2.7  0.222   -5.0 1.5 1.530  9.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8    RT     RH   DQ    LH   GAMMA
 12  0.23  10.4    4.3  -3.7 -0.04  78.4 0.16 0.000   9.22
  TE    QE
 0.012 -0.032
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.7  -0.5     0.0    0.024  -0.048   1.31
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.562 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 2.8

VALID: 9DEC81/12Z TO 10DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  8.2    4.0   0.167    7.0 2.5  0.083   -2.5 2.6 1.535  7.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8    RT     RH   DQ    LH   GAMMA
 12  0.16  10.2    5.5  -1.0 -0.18  96.7 0.13 0.158   7.30
  TE    QE
 0.009 -0.031
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.8  -1.5     1.1    0.080  -0.193   1.70
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.535 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.8
```

```
VALID: 10DEC81/12Z TO 11DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA   DQS     T8   Q8   Z8     U
 7.1    6.0    0.375    6.1 2.5  0.213  -2.0 2.9 1.525  7.4
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS      TA     T8     RT     RH   DQ   LH   GAMMA
 12  0.12  10.1    6.3   -1.7 -0.16  94.7 0.14 0.180   7.71
  TE    QE
 0.009 -0.021
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 0.7  -1.1     0.7    0.064  -0.093   1.05
AIR COLUMN WAS OVER WATER  6  HOURS
DEPTH OF PBL = 1.525 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.2
```

```
VALID: 16DEC81/12Z TO 17DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA   DQS     T8   Q8   Z8     U
 6.4    6.0    0.375    6.0 3.5  0.175  -6.0 1.8 1.595  7.1
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS      TA     T8     RT     RH   DQ   LH   GAMMA
 12  0.07   8.7    5.9   -6.1 -0.04  77.7 0.09 0.000   9.27
  TE    QE
 0.011 -0.014
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 0.3  -0.5     0.0    0.023  -0.022   0.50
AIR COLUMN WAS OVER WATER  6  HOURS
DEPTH OF PBL = 1.622 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 2.7
```

```
VALID: 19DEC81/12Z TO 20DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA   DQS     T8   Q8   Z8     U
 5.2  -5.0    0.300    5.5 0.8  0.200  -9.0 1.3 1.450 14.7
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS      TA     T8     RT     RH   DQ   LH   GAMMA
 12  0.46   8.2    1.7   -2.3 -0.19 101.6 0.28 0.349   7.24
  TE    QE
 0.010 -0.050
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 5.9  -1.5     2.2    0.133  -0.339   2.96
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.7 CM
CLOUD AMOUNT = 7.3
```

```
VALID: 22DEC81/12Z TO 23DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  5.1   0.0   0.500    5.5 1.7  0.213  -7.5 1.1 1.455 12.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT     RH   DQ   LH   GAMMA
 12  0.36   9.1   2.3  -5.2 -0.13  82.7 0.21 0.041   9.86
  TE    QE
 0.024 -0.077
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.7  -0.5     0.0    0.092  -0.209   1.71
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.6

VALID: 23DEC81/12Z TO 24DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  5.1  -3.0   0.400    5.5 2.0  0.170  -8.5 0.9 1.499 11.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT     RH   DQ   LH   GAMMA
 12  0.41   9.1   0.9  -4.6 -0.04  75.3 0.18 0.000   9.19
  TE    QE
 0.012 -0.039
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 4.2  -0.5     0.0    0.131  -0.238   1.82
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.565 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 1.8

VALID: 25DEC81/12Z TO 26DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  8.8   5.0   0.000    7.0 4.0  0.000   3.5 1.9 1.490  8.8
VERTICAL VELOCITY OF AIR PARCEL =  1  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT     RH   DQ   LH   GAMMA
 12  0.23   8.8   3.0   1.5 -0.04  58.7 0.08 0.000   4.89
  TE    QE
 0.001 -0.003
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.3  -0.5     0.0    0.014  -0.024   1.18
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.490 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

```
VALID: 30DEC81/12Z TO 31DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  5.6   0.0   0.250    5.7 1.5  0.108  -9.0 0.9 1.470  4.8
VERTICAL VELOCITY OF AIR PARCEL =  .5  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.16   8.6    0.6  -8.4 -0.04  71.2 0.10 0.000  11.54
  TE     QE
 0.023 -0.048
SENS.    RAD.     LAT.    T.ENT.  Q.ENT.   Q.TOT.
 1.7  -0.5      0.0     0.187  -0.281    1.13
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.587 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.6

VALID: 9DEC81/00Z TO 9DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  7.4   4.0   0.300    6.5 3.5  0.150  -4.5 1.5 1.540 10.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.21  10.4    5.5  -3.0 -0.04  76.8 0.14 0.000   8.73
  TE     QE
 0.001 -0.003
SENS.    RAD.     LAT.    T.ENT.  Q.ENT.   Q.TOT.
 1.9  -0.5      0.0     0.014  -0.021    1.38
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.580 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 1.3

VALID: 13DEC81/00Z TO 13DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  6.8  -1.0   0.300    6.1 1.7  0.150 -11.0 0.9 1.540  9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.31   9.8    2.0  -8.0 -0.10  83.9 0.18 0.031  11.59
  TE     QE
 0.044 -0.120
SENS.    RAD.     LAT.    T.ENT.  Q.ENT.   Q.TOT.
 3.2  -0.7      0.1     0.339  -0.636    1.82
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.640 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
```

```
VALID: 14DEC81/00Z TO 14DEC/12Z
--INITIAL CONDITIONS--
  TS    TA     DTS     QS  QA   DQS    T8   Q8   Z8    U
  6.7  -2.0   0.300   6.1 1.5  0.150 -10.5 0.9 1.505 14.7
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.41   9.7   3.4  -5.1 -0.14  96.8 0.25 0.227   9.82
  TE    QE
 0.022 -0.100
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 5.0  -1.0     1.2    0.244  -0.599   2.72
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.602 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0


VALID: 15DEC81/00Z TO 15DEC/12Z
--INITIAL CONDITIONS--
  TS    TA     DTS     QS  QA   DQS    T8   Q8   Z8    U
  6.5  -2.0   0.273   6.0 1.2  0.136 -10.9 0.6 1.535  8.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.31   9.8   1.4  -6.6 -0.11  83.2 0.17 0.041  10.66
  TE    QE
 0.022 -0.083
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.8  -0.6     0.1    0.157  -0.385   2.12
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.655 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 7.5


VALID: 19DEC81/00Z TO 19DEC/12Z
--INITIAL CONDITIONS--
  TS    TA     DTS     QS  QA   DQS    T8   Q8   Z8    U
  6.3  -7.0   0.500   6.0 0.8  0.233 -10.5 0.6 1.455 18.9
VERTICAL VELOCITY OF AIR PARCEL =  1.5  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  1.17   9.3  -3.8  -7.3 -0.18  95.3 0.40 0.361  11.41
  TE    QE
 0.048 -0.185
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 7.7  -0.9     0.9    0.342  -0.636   2.55
AIR COLUMN WAS OVER WATER  6  HOURS
DEPTH OF PBL = 1.515 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
```

```
VALID: 20DEC81/00Z TO 20DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8   Q8   Z8     U
  6.2   0.0    0.300    5.8 1.5   0.140   -4.0 1.6 1.480 10.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.32   9.2    2.5   -1.5  -0.17   83.2  0.18 0.077    7.26
  TE     QE
 0.010 -0.038
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 3.1  -0.7      0.1     0.032  -0.092    1.93
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.480 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 1.5


VALID: 23DEC81/00Z TO 23DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8   Q8   Z8     U
  6.1  -7.0    0.273    5.8 1.2   0.126 -12.5 0.6 1.455 12.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.52   9.1   -0.5   -6.0  -0.14   84.9  0.22 0.064   10.38
  TE     QE
 0.023 -0.092
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 6.8  -0.8      0.2     0.275  -0.673    2.55
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.565 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 7.4


VALID: 29DEC81/00Z TO 29DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8   Q8   Z8     U
  5.9 -10.0    0.273    5.7 0.8   0.127 -14.0 0.6 1.465 12.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.61   8.9   -2.4   -6.4  -0.15   84.7  0.24 0.077   10.45
  TE     QE
 0.023 -0.087
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 8.1  -1.1      0.3     0.355  -0.913    2.72
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.575 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 7.5
```

```
VALID: 31DEC81/00Z TO 31DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8    U
 5.6   -8.0    0.027    5.7 1.7  0.118 -15.0 0.6 1.470 11.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.42   5.9   -2.3   -9.3 -0.13  87.3 0.19 0.123  10.31
  TE     QE
 0.023 -0.070
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 6.1  -1.0     0.3     0.353  -0.741    2.15
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.580 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 8.0


VALID: 9JAN82/12Z TO 10JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8    U
 4.7    5.0    0.500    5.5 3.8  0.300  -3.5 1.7 1.460  7.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.08   7.7    4.8   -3.7 -0.04  60.1 0.09 0.000   7.81
  TE     QE
 0.001 -0.001
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 0.2  -0.5     0.0     0.015  -0.010    0.45
AIR COLUMN WAS OVER WATER  6  HOURS
DEPTH OF PBL = 1.460 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0


VALID: 10JAN82/12Z TO 11JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8    U
 7.7    7.0    0.000    6.3 5.5  0.000   6.5 2.2 1.460  7.5
VERTICAL VELOCITY OF AIR PARCEL =  1  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.14   7.7    3.4    2.9 -0.04  43.3 0.02 0.000   3.26
  TE     QE
 0.001 -0.001
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 1.0  -0.5     0.0     0.015  -0.011    0.28
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.460 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

```
VALID: 13JAN82/12Z TO 14JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS      T8    Q8    Z8     U
  3.3  -8.0   0.555    4.9 0.9   0.189 -13.5 0.4 1.470 10.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.54   8.3  -3.3  -8.8 -0.04  73.2 0.20 0.000  11.62
  TE     QE
 0.023 -0.068
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 4.9  -0.5     0.0     0.263  -0.400   1.76
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.560 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 6.4

VALID: 20JAN82/12Z TO 21JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS      T8    Q8    Z8     U
  3.2   2.0   0.500    4.8 1.8   0.175  -2.0 0.9 1.490 12.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.29   9.2   3.8  -0.2 -0.04  62.6 0.17 0.000   6.31
  TE     QE
 0.001 -0.005
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 2.2  -0.5     0.0     0.014  -0.034   2.03
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.490 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 9JAN82/00Z TO 9JAN/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS      T8    Q8    Z8     U
  3.8  -5.0   0.444    4.7 2.2   0.222  -4.0 1.5 1.440 11.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.47   7.8  -1.2  -0.2 -0.04  61.8 0.16 0.000   5.55
  TE     QE
 0.001 -0.004
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 4.2  -0.5     0.0     0.015  -0.020   1.34
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.440 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

```
VALID: 31JAN82/12Z TO 1FEB/00Z
--INITIAL CONDITIONS--
  TS    TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  3.4  -3.0   0.333   4.8 2.0  0.133 -12.5 0.6 1.460  8.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.28   7.1  -0.2  -9.7 -0.04  70.1 0.13 0.000  11.49
  TE    QE
 0.023 -0.052
SENS.  RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.0  -0.5    0.0    0.237  -0.357   1.31
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.570 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.1


VALID: 1FEB82/12Z TO 2FEB/00Z
--INITIAL CONDITIONS--
  TS    TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  3.4  -3.0   0.364   4.8 1.2  0.127 -10.5 0.7 1.510  9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.30   7.4  -0.2  -7.7 -0.12  80.3 0.15 0.004   9.98
  TE    QE
 0.023 -0.070
SENS.  RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.2  -0.5    0.0    0.140  -0.270   1.65
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.592 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.1


VALID: 4FEB82/12Z TO 5FEB/00Z
--INITIAL CONDITIONS--
  TS    TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  3.2  -5.0   0.333   4.7 0.7  0.125 -16.5 0.4 1.485 12.6
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.37   7.2   0.4 -11.1 -0.11  96.4 0.21 0.099  12.34
  TE    QE
 0.045 -0.148
SENS.  RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 5.1  -1.0    0.8    0.462  -1.109   2.58
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.605 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
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```
VALID: 5FEB82/12Z TO 6FEB/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  3.2  -1.0    0.333    4.7 1.4   0.125 -12.5 0.8 1.460  7.4
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.20   7.2    0.9 -10.6 -0.09  82.4 0.12 0.012  12.21
  TE    QE
 0.046 -0.099
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 2.1  -0.6      0.0     0.328  -0.545   1.40
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.580 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0

VALID: 6FEB82/12Z TO 7FEB/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  3.2  -9.0    0.333    4.7 0.7   0.125 -18.0 0.6 1.480  8.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.41   7.2   -3.5 -12.5 -0.13  95.7 0.17 0.080  13.33
  TE    QE
 0.045 -0.112
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 5.4  -1.2      0.8     0.488  -0.875   1.93
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.600 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0

VALID: 14FEB82/12Z TO 15FEB/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  2.8   0.0    0.333    4.6 1.9   0.200  -5.5 1.3 1.510  6.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.15   6.1    0.8   -4.7 -0.04  67.7 0.11 0.000   7.19
  TE    QE
 0.001 -0.003
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 1.2  -0.5      0.0     0.014  -0.017   0.95
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

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VALID: 19JAN82/12Z TO 20JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  3.0  -4.0   0.417   4.8 1.3  0.142 -10.5 0.6 1.465  8.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.31   8.0  -0.9  -7.4 -0.04  72.4 0.13 0.000  10.49
  TE    QE
 0.011 -0.034
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.4  -0.5    0.0    0.142  -0.251   1.59
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.567 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 3.7

VALID: 15FEB82/00Z TO 15FEB/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  5.7  -4.0   0.111   5.7 2.0  0.044   -4.0 1.4 1.510  7.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.29   6.7  -1.6  -1.6 -0.04  59.3 0.11 0.000   5.52
  TE    QE
 0.001 -0.003
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.8  -0.5    0.0    0.014  -0.017   1.05
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 24FEB82/00Z TO 24FEB/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  3.6  -2.0   0.250   4.8 2.5  0.100   -8.0 0.9 1.510  7.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 12  0.22   6.6   0.0  -6.0 -0.04  62.6 0.08 0.000   8.32
  TE    QE
 0.001 -0.003
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.5  -0.5    0.0    0.014  -0.020   0.98
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.540 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

```
VALID: 26FEB82/00Z TO 26FEB/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  3.5    4.0    0.300    4.8 3.5   0.110   -3.5  1.4  1.520   7.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.07   6.2    3.8   -3.7  -0.04   52.4  0.06  0.000   6.49
  TE     QE
 0.001 -0.002
SENS.    RAD.    LAT.    T.ENT.   Q.ENT.   Q.TOT.
 0.3   -0.5      0.0     0.014   -0.011    0.46
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.520 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 0.0

VALID: 7FEB82/12Z TO 8FEB/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  3.1   -4.0    0.333    4.7 2.0   0.125  -13.0  1.0  1.505   5.1
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 12  0.19   7.1   -2.0  -11.0  -0.04   79.5  0.09  0.000  12.05
  TE     QE
 0.022 -0.034
SENS.    RAD.    LAT.    T.ENT.   Q.ENT.   Q.TOT.
 2.2   -0.5      0.0     0.240   -0.266    0.83
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.625 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 9.0
```

VALID: 19DEC81/00Z TO 19DEC/12Z

--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
6.3	-7.0	0.500	6.0	0.8	0.233	-10.5	0.6	1.455	18.9

VERTICAL VELOCITY OF AIR PARCEL = 1.5 CM/S

--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.00	6.3	-7.4	-10.9	-0.04	29.6	0.00	0.000	11.85
2	0.00	6.3	-7.9	-11.4	-0.04	30.6	0.00	0.000	12.14
3	0.00	6.3	-8.3	-11.8	-0:04	31.0	0.00	0.000	12.43
4	0.00	6.3	-8.7	-12.2	-0.04	31.4	0.00	0.000	12.73
5	0.00	6.3	-9.1	-12.6	-0.04	31.8	0.00	0.000	13.02
6	0.00	6.3	-9.6	-13.1	-0.04	32.3	0.00	0.000	13.31
7	1.41	6.8	-8.6	-12.1	-0.04	32.8	0.47	0.000	12.97
8	1.36	7.3	-7.6	-11.1	-0.04	55.9	0.44	0.000	12.67
9	1.31	7.8	-6.8	-10.3	-0.04	73.2	0.43	0.000	12.41
10	1.27	8.3	-5.9	-9.4	-0.17	86.3	0.41	0.133	12.15
11	1.23	8.8	-4.8	-8.3	-0.18	92.9	0.40	0.411	11.75
12	1.17	9.3	-3.8	-7.3	-0.18	95.3	0.40	0.361	11.41

TE	QE
0.048	-0.185

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
7.7	-0.9	0.9	0.342	-0.636	2.55

AIR COLUMN WAS OVER WATER 6 HOURS

DEPTH OF PBL = 1.515 KM

PRECIP WATER = 0.0 GRAMS

SNOWFALL = 0.0 CM

CLOUD AMOUNT = 9.0

VALID: 15DEC81/00Z TO 15DEC/12Z

--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
6.5	-2.0	0.273	6.0	1.2	0.126	-10.0	0.6	1.535	9.8

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S

--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.33	6.8	-1.7	-9.7	-0.04	28.4	0.19	0.000	10.73
2	0.33	7.0	-1.4	-9.4	-0.04	36.2	0.19	0.000	10.71
3	0.33	7.3	-1.1	-9.1	-0.04	43.2	0.18	0.000	10.69
4	0.32	7.6	-0.8	-8.8	-0.04	49.7	0.18	0.000	10.67
5	0.32	7.9	-0.5	-8.5	-0.04	55.5	0.18	0.000	10.66
6	0.32	8.1	-0.2	-8.2	-0.04	60.9	0.18	0.000	10.65
7	0.31	8.4	0.1	-7.9	-0.04	65.7	0.17	0.000	10.64
8	0.31	8.7	0.4	-7.6	-0.04	70.2	0.17	0.000	10.63
9	0.31	9.0	0.7	-7.3	-0.04	74.2	0.17	0.000	10.62
10	0.31	9.2	0.9	-7.1	-0.04	77.9	0.17	0.000	10.62
11	0.31	9.5	1.2	-6.8	-0.11	81.3	0.17	0.016	10.64
12	0.31	9.8	1.4	-6.6	-0.11	83.2	0.17	0.041	10.66

TE QE
0.022 -0.083

SENS. RAD. LAT. T.ENT. Q.ENT. Q.TOT.
3.8 -0.6 0.1 0.157 -0.385 2.12

AIR COLUMN WAS OVER WATER 12 HOURS
DEPTH OF PBL = 1.655 KM
PRECIP WATER = 0.0 GRAMS
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 7.5

18-HOUR FORECAST RESULTS

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VALID: 20SEP82/00Z TO 20SEP/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS   QA    DQS     T8    Q8    Z8     U
 18.6  13.5   0.500  14.0 5.5  0.375   4.0 1.8 1.465 13.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ    LH   GAMMA
 18  0.38  22.6  15.9   6.4 -0.04  71.0 0.46 0.000  10.92
  TE    QE
 0.012 -0.078
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.8  -0.7    0.0    0.204  -0.396   3.90
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.565 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.2

VALID: 22SEP82/12Z TO 23SEP/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS   QA    DQS     T8    Q8    Z8     U
 18.0  18.5   0.222  13.0 9.9  0.179  10.0 4.5 1.500   5.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ    LH   GAMMA
 18  0.08  22.0  18.5  10.0 -0.04  65.7 0.11 0.000   8.01
  TE    QE
 0.001 -0.004
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 0.6  -0.7    0.0    0.022  -0.041   1.62
AIR COLUMN WAS OVER WATER  18  HOURS
DEPTH OF PBL = 1.500 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 26SEP82/00Z TO 26SEP/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS   QA    DQS     T8    Q8    Z8     U
 17.7  10.5   0.400  12.3 2.3  0.420  -1.0 1.5 1.515 12.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ    LH   GAMMA
 18  0.36  21.7  14.8   3.3 -0.12  88.8 0.53 0.204  12.17
  TE    QE
 0.045 -0.325
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.9  -1.0    0.9    0.487  -1.652   5.25
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.615 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
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VALID: 26SEP82/12Z TO 27SEP/06Z
--INITIAL CONDITIONS--
  TS    TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
 17.7  15.0   0.500   12.2 2.7  0.575    2.5 1.3 1.515  9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 18  0.22  21.7  16.0   3.5 -0.04  67.5 0.45 0.000  12.02
  TE     QE
 0.023 -0.127
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.4  -0.7     0.0    0.246  -0.543   3.42
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.595 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.4

VALID: 27SEP82/00Z TO 27SEP/18Z
--INITIAL CONDITIONS--
  TS    TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
 17.7  13.0   0.500   12.2 3.0  0.575    3.0 1.2 1.520  9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 18  0.30  22.7  15.1   5.1 -0.04  69.4 0.45 0.000  11.56
  TE     QE
 0.022 -0.155
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.6  -0.7     0.0    0.232  -0.685   4.21
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.617 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.0

VALID: 15OCT82/00Z TO 15OCT/18Z
--INITIAL CONDITIONS--
  TS    TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
 13.8   8.0   0.364    9.5 2.5  0.318    0.0 1.4 1.570 12.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 18  0.34  17.8  11.0   3.0 -0.13  83.2 0.35 0.082   9.40
  TE     QE
 0.022 -0.149
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.6  -0.8     0.1    0.131  -0.537   3.91
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.650 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.8
```

```
VALID: 15OCT82/12Z TO 16OCT/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
 13.8  10.0   0.267  10.0 2.5  0.200   1.5 1.3 1.560  7.4
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH    DQ    LH    GAMMA
 18  0.18  17.8  11.8   3.3 -0.04  76.8 0.23 0.000   9.32
  TE     QE
 0.011 -0.072
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 2.4  -0.7     0.0     0.060  -0.306   3.49
AIR COLUMN WAS OVER WATER  15  HOURS
DEPTH OF PBL = 1.640 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 2.5


VALID: 16OCT82/12Z TO 17OCT/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
 13.8  10.0   0.444   9.8 3.7  0.300   7.0 5.5 1.510 11.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH    DQ    LH    GAMMA
 18  0.27  17.8  12.4   9.4 -0.24  91.5 0.31 0.403   5.57
  TE     QE
 0.010 -0.048
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 2.2  -1.9     2.0     0.080  -0.234   2.77
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.1


VALID: 17OCT82/00Z TO 17OCT/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
 13.5  10.0   0.800   9.8 2.5  0.480   7.0 5.0 1.480 14.7
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH    DQ    LH    GAMMA
 18  0.40  17.5  11.5   8.5 -0.22  87.8 0.50 0.476   6.06
  TE     QE
 0.010 -0.042
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 1.7  -1.2     1.0     0.047  -0.110   2.49
AIR COLUMN WAS OVER WATER  5  HOURS
DEPTH OF PBL = 1.480 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 3.9
```

```
VALID: 17OCT82/12Z TO 18OCT/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8    Q8   Z8    U
 13.2  14.0   0.308   9.5 5.0  0.128   9.0 4.9 1.420 10.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 18  0.15  17.2  13.9   8.9 -0.20  84.5 0.18 0.072   5.83
  TE    QE
 0.010 -0.051
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 0.8  -1.2    0.2    0.049  -0.177   2.56
AIR COLUMN WAS OVER WATER  13  HOURS
DEPTH OF PBL = 1.420 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 1.9

VALID: 18OCT82/12Z TO 19OCT/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8    Q8   Z8    U
 13.4  11.0   0.308   9.5 3.8  0.177   3.0 2.5 1.460 14.7
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 18  0.24  17.4  14.1   6.1 -0.19  90.9 0.29 0.343   7.76
  TE    QE
 0.010 -0.077
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.9  -1.5    1.5    0.074  -0.419   4.28
AIR COLUMN WAS OVER WATER  13  HOURS
DEPTH OF PBL = 1.460 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.0

VALID: 19OCT82/00Z TO 19OCT/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8    Q8   Z8    U
 13.2  10.0   0.500   9.2 2.5  0.350   1.5 2.1 1.450 18.9
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 18  0.34  17.2  13.6   5.1 -0.18  92.8 0.49 0.653   8.34
  TE    QE
 0.010 -0.074
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.9  -1.2    1.9    0.056  -0.264   4.26
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.490 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.5
```

```
VALID: 19OCT82/12Z TO 20OCT/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
 13.2  13.5   0.286    9.5 3.8  0.193    5.5 2.6 1.460 10.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.15  17.2  13.9   5.9 -0.16  84.9 0.24 0.091   7.73
  TE    QE
 0.010 -0.068
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.1  -0.9     0.2    0.039  -0.185   3.56
AIR COLUMN WAS OVER WATER  14  HOURS
DEPTH OF PBL = 1.460 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 2.0

VALID: 22OCT82/12Z TO 23OCT/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
 12.8  10.0   0.364    9.2 5.4  0.255    0.0 3.8 1.545  5.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.14  16.8  10.3   0.3 -0.14 100.1 0.12 0.111  10.67
  TE    QE
 0.022 -0.045
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.3  -2.5     1.2    0.300  -0.333   1.19
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.635 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0

VALID: 23OCT82/00Z TO 23OCT/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
 12.6   4.0   0.333    9.0 3.0  0.233   -4.5 2.0 1.565  8.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.32  16.6   7.7  -0.8 -0.13  87.2 0.25 0.084  11.12
  TE    QE
 0.043 -0.160
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.9  -1.3     0.6    0.488  -1.126   2.83
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.685 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
```

VALID: 24OCT82/00Z TO 24OCT/18Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
12.4	0.0	0.500	9.0	0.8	0.350	-4.5	0.9	1.525	14.7

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
18	0.66	16.9	6.6	2.1	-0.17	87.8	0.47	0.303	9.68

TE	QE
0.022	-0.165

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
6.7	-1.1	0.7	0.338	-0.736	4.50

AIR COLUMN WAS OVER WATER 9 HOURS
DEPTH OF PBL = 1.612 KM
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 6.8

VALID: 24OCT82/12Z TO 25OCT/06Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
12.3	15.0	0.400	9.0	1.5	0.280	4.5	2.0	1.525	13.2

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
18	0.09	16.3	14.9	4.4	-0.16	92.9	0.38	0.479	7.82

TE	QE
0.009	-0.072

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
-0.1	-1.0	0.9	0.046	-0.228	4.11

AIR COLUMN WAS OVER WATER 10 HOURS
DEPTH OF PBL = 1.525 KM
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 4.6

VALID: 25OCT82/00Z TO 25OCT/18Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
12.3	5.0	0.308	9.0	2.5	0.215	4.5	4.0	1.530	11.5

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
18	0.36	16.3	9.4	8.9	-0.24	89.1	0.30	0.230	4.83

TE	QE
0.009	-0.068

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
4.9	-2.2	1.6	0.087	-0.430	4.03

AIR COLUMN WAS OVER WATER 13 HOURS
DEPTH OF PBL = 1.530 KM
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 3.4

```
VALID: 5NOV82/00Z TO 5NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
 10.8   8.0   0.333   8.0 6.2  0.208    5.0 5.0 1.540  5.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8    RT    RH   DQ   LH   GAMMA
 18  0.17  14.8   7.9   4.9 -0.20  88.4 0.09 0.069   6.44
  TE    QE
 0.009 -0.017
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.5  -2.1     0.4    0.095  -0.112   0.82
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.540 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 3.2

VALID: 9NOV82/00Z TO 9NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
 10.2   4.0   0.444   7.8 3.0  0.256   -4.5 2.3 1.490 11.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8    RT    RH   DQ   LH   GAMMA
 18  0.33  14.2   7.4  -1.1 -0.15  96.7 0.25 0.251  10.29
  TE    QE
 0.023 -0.083
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.0  -1.4     1.5    0.284  -0.472   2.22
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.580 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0

VALID: 9NOV82/12Z TO 10NOV/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
 10.0   3.0   0.210   7.5 2.5  0.165   -3.5 2.5 1.485 12.0
VERTICAL VELOCITY OF AIR PARCEL =  2  CM/S
--RESULTS--
TIME  SH    TS     TA     T8    RT    RH   DQ   LH   GAMMA
 18  0.46  12.9   3.9  -2.6 -0.16 103.4 0.23 0.233  10.45
  TE    QE
 0.022 -0.069
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 6.5  -2.5     3.8    0.361  -0.759   3.49
AIR COLUMN WAS OVER WATER  14  HOURS
DEPTH OF PBL = 1.625 KM
SNOWFALL =  13.8 CM
CLOUD AMOUNT = 9.0
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VALID: 10NOV82/00Z TO 10NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8   Q8   Z8     U
 10.0    9.0   0.333    7.5 6.8  0.193    1.5 5.0 1.409 18.5
VERTICAL VELOCITY OF AIR PARCEL =  2  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.49  14.0   8.3    0.8 -0.18 101.5 0.14 0.219    9.43
  TE    QE
 0.025 -0.001
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 4.7  -3.4      3.8    0.243   0.028   1.32
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.455 KM
SNOWFALL =  15.1 CM
CLOUD AMOUNT = 9.0


VALID: 10NOV82/12Z TO 11NOV/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8   Q8   Z8     U
 10.0    4.5   0.444    7.5 3.8  0.256    1.0 3.5 1.410 17.5
VERTICAL VELOCITY OF AIR PARCEL =  2  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.85  14.0   3.5    0.0 -0.21 101.8 0.29 0.364    9.90
  TE    QE
 0.024 -0.057
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 8.2  -3.2      3.4    0.333  -0.295   2.69
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.495 KM
SNOWFALL =  13.0 CM
CLOUD AMOUNT = 9.0


VALID: 17NOV82/00Z TO 17NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8   Q8   Z8     U
  9.0    4.0   0.267    7.1 3.8  0.153    4.0 2.5 1.528  7.8
VERTICAL VELOCITY OF AIR PARCEL =  1.5  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.48  13.0  -1.1   -1.1 -0.23  97.9 0.13 0.146    9.25
  TE    QE
 0.009 -0.034
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 5.5  -1.6      0.6    0.062  -0.174   1.87
AIR COLUMN WAS OVER WATER  15  HOURS
DEPTH OF PBL = 1.548 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
```

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VALID: 18NOV82/12Z TO 19NOV/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  8.9  11.0   0.267    7.1 6.2  0.153   1.0 3.4 1.535  5.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.06  12.9  10.2   0.2 -0.13  85.4 0.06 0.044   8.29
  TE    QE
 0.009 -0.014
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 0.1  -1.1     0.1    0.062  -0.073   0.62
AIR COLUMN WAS OVER WATER  15  HOURS
DEPTH OF PBL = 1.540 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 3.1

VALID: 19NOV82/00Z TO 19NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  8.7   6.0   0.500    6.7 4.0  0.288  -3.0 2.4 1.510  7.4
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.19  12.7   6.5  -2.5 -0.12  83.1 0.13 0.042  10.06
  TE    QE
 0.023 -0.043
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.2  -0.8     0.1    0.087  -0.125   0.90
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.555 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 6.2

VALID: 21NOV82/12Z TO 22NOV/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  8.5   8.0   0.444    6.8 6.0  0.256  -1.5 2.9 1.490 15.7
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.25  12.5   8.8  -0.7 -0.14  87.1 0.15 0.124   8.85
  TE    QE
 0.010 -0.019
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.5  -1.0     0.3    0.055  -0.074   0.97
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.8
```

```
VALID: 22NOV82/00Z TO 22NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  8.4    1.0    0.364    6.9 0.9  0.209 -11.0 0.8 1.485 11.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH   GAMMA
 18  0.33  12.4    5.8   -6.2 -0.12  99.2 0.31 0.168  12.54
  TE    QE
 0.045 -0.196
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 4.1  -1.2      1.4     0.564  -1.321    3.35
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.595 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 9.0

VALID: 23NOV82/12Z TO 24NOV/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  8.3    4.0    0.444    6.8 1.0  0.256 -11.0 0.6 1.515 13.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH   GAMMA
 18  0.29  12.3    7.3   -7.7 -0.09 101.7 0.34 0.224  13.23
  TE    QE
 0.045 -0.190
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 2.6  -0.9      1.1     0.512  -1.011    3.03
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.605 KM
SNOWFALL =    0.4 CM
CLOUD AMOUNT = 9.0

VALID: 29NOV82/00Z TO 29NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  7.4    0.0    0.400    6.3 2.6  0.230  -6.0 1.8 1.460  9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH   GAMMA
 18  0.36  11.4    3.0   -3.0 -0.16  87.8 0.19 0.120   9.89
  TE    QE
 0.023 -0.072
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 3.5  -1.1      0.3     0.255  -0.382    1.78
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.535 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 7.3
```

```
VALID: 29NOV82/12Z TO 30NOV/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8   Q8   Z8    U
  7.4    2.0    0.444    6.3 1.5  0.256  -5.0 1.1 1.450 13.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.39  11.4   4.8  -2.2 -0.16  85.2 0.29 0.184  9.35
  TE    QE
 0.024 -0.110
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.4  -0.9    0.2    0.111  -0.369   2.61
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.3

VALID: 12OCT82/00Z TO 12OCT/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8   Q8   Z8    U
 14.0  18.0    0.000   10.0 9.9  0.000   12.0 4.5 1.570  3.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  -.04  14.0   16.5  10.5 -0.04  47.6 0.00 0.000  2.25
  TE    QE
 0.001 -0.001
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
-0.9  -0.7    0.0    0.021  -0.011   0.03
AIR COLUMN WAS OVER WATER  18  HOURS
DEPTH OF PBL = 1.570 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 18OCT82/00Z TO 18OCT/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8   Q8   Z8    U
 13.4  14.0    0.000    9.6 8.0  0.000   14.0 3.3 1.500  7.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.00  13.4   13.2  13.2 -0.04  34.5 0.03 0.000  0.10
  TE    QE
 0.001 -0.002
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
-0.1  -0.7    0.0    0.022  -0.024   0.69
AIR COLUMN WAS OVER WATER  16  HOURS
DEPTH OF PBL = 1.500 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

```
VALID: 5OCT82/00Z TO 5OCT/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8   Q8   Z8    U
 12.0  18.0   0.167   8.5 8.0  0.139  10.0 6.0 1.540  3.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 18  -.02  15.0  16.3   8.3 -0.04  78.1 0.04 0.000   4.35
  TE     QE
 0.001 -0.001
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
-1.0  -0.7     0.0    0.021  -0.017   0.43
AIR COLUMN WAS OVER WATER  18  HOURS
DEPTH OF PBL = 1.540 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 24SEP82/00Z TO 24SEP/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8   Q8   Z8    U
 14.8  18.0   0.333  10.0 9.9  0.422  10.0 4.0 1.500 15.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 18  0.05  17.8  16.8   8.8 -0.04  56.5 0.19 0.000   6.02
  TE     QE
 0.001 -0.002
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
-0.6  -0.7     0.0    0.022  -0.016   0.95
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.500 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 11OCT82/12Z TO 12OCT/06Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8   Q8   Z8    U
 11.2  17.0   0.200   8.0 7.5  0.200   5.0 3.5 1.540  8.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 18  -.03  14.2  14.7   2.7 -0.04  77.9 0.09 0.000   7.49
  TE     QE
 0.001 -0.002
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
-1.7  -0.7     0.0    0.021  -0.021   0.89
AIR COLUMN WAS OVER WATER  15  HOURS
DEPTH OF PBL = 1.540 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

```
VALID: 23SEP82/00Z TO 23SEP/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
 15.0  15.0   0.200  10.5 8.0  0.200   6.2 4.0 1.510  7.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.09  18.0  15.1    6.3 -0.04  77.7 0.13 0.000   7.73
  TE    QE
 0.001 -0.004
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 0.8  -0.7     0.0    0.021  -0.036   1.64
AIR COLUMN WAS OVER WATER  15  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 25SEP82/00Z TO 25SEP/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
 17.7  21.0   0.000  13.2 9.9  0.000  13.5 6.0 1.520  3.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  -.03  17.7  19.6  12.1 -0.04  63.8 0.04 0.000   3.68
  TE    QE
 0.001 -0.002
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
-0.7  -0.7     0.0    0.021  -0.028   0.83
AIR COLUMN WAS OVER WATER  18  HOURS
DEPTH OF PBL = 1.520 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 11NOV82/00Z TO 11NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  9.9   0.0   0.571   7.5 1.5  0.329  -1.0 2.0 1.410 20.4
VERTICAL VELOCITY OF AIR PARCEL =  1.5  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  1.13  13.9   2.5    1.5 -0.23 100.3 0.50 0.595   8.79
  TE    QE
 0.024 -0.144
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 9.4  -1.8     3.6    0.344  -0.731   3.79
AIR COLUMN WAS OVER WATER  7  HOURS
DEPTH OF PBL = 1.472 KM
SNOWFALL =   0.3 CM
CLOUD AMOUNT = 8.9
```

```
VALID: 24NOV82/00Z TO 24NOV/18Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  8.1   -5.0   0.444    6.7 0.9  0.256 -13.5 0.8 1.525 12.6
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ   LH   GAMMA
 18  0.57  12.1    1.7   -6.8 -0.14  99.9 0.33 0.222  12.40
  TE     QE
 0.045 -0.179
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 6.0  -1.3     1.5    0.532  -1.000   2.91
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.615 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
```

24-HOUR FORECAST RESULTS

```
VALID: 12NOV81/00Z TO 13NOV/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     TS    Q8    Z8     U
 13.6  10.0    0.000    9.8 2.6  0.000    3.0 2.2 1.520  5.6
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 24  0.09  13.6  10.3    3.3 -0.04  69.4 0.14 0.000   6.81
  TE    QE
 0.001 -0.005
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 1.1  -0.9      0.0    0.026  -0.040   1.92
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.520 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
```

```
VALID: 17NOV81/00Z TO 18NOV/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8    Q8    Z8     U
  9.9  -6.0    0.176    7.5 1.6  0.094   -7.5 1.7 1.515  7.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 24  0.37  12.9    0.1   -1.4 -0.18  88.6 0.16 0.068   9.45
  TE    QE
 0.022 -0.089
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 7.3  -2.6      0.9    0.503  -0.990   2.88
AIR COLUMN WAS OVER WATER  17  HOURS
DEPTH OF PBL = 1.670 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 6.6
```

```
VALID: 18NOV81/00Z TO 19NOV/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8    Q8    Z8     U
 12.8   5.0    0.000    9.1 2.0  0.000    0.0 4.0 1.520  5.9
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 24  0.16  12.8    6.7    1.7 -0.19 101.2 0.13 0.163   7.33
  TE    QE
 0.009 -0.024
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.8  -4.5      3.1    0.294  -0.308   2.24
AIR COLUMN WAS OVER WATER  14  HOURS
DEPTH OF PBL = 1.597 KM
SNOWFALL =   7.9 CM
CLOUD AMOUNT = 7.2
```

```
VALID: 27NOV81/00Z TO 28NOV/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  8.6 -10.0   0.273   6.8 0.9  0.136 -16.5 0.8 1.535 12.6
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 24  0.63  11.6   0.1  -6.4 -0.15  97.9 0.28 0.160  11.76
  TE    QE
 0.044 -0.178
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 9.1  -1.9     2.1    0.733  -1.328   3.31
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.645 KM
SNOWFALL =   0.9 CM
CLOUD AMOUNT = 9.0


VALID: 8NOV81/12Z TO 9NOV/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     TS   Q8   Z8     U
 11.4   5.0   0.270   0.5 1.7  0.150  -7.5 0.9 1.545  7.0
VERTICAL VELOCITY OF AIR PARCEL =  1  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 24  0.25  14.4   5.6  -6.9 -0.04  25.3 0.02 0.000  13.74
  TE    QE
 0.022 -0.001
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.7  -0.9     0.0    0.528  -0.129  -0.08
AIR COLUMN WAS OVER WATER  11  HOURS
DEPTH OF PBL = 1.655 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0


VALID: 14NOV82/12Z TO 15NOV/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
 13.3  13.0   0.000   9.5 7.1  0.000   8.0 3.3 1.500  8.9
VERTICAL VELOCITY OF AIR PARCEL =  1.5  CM/S
--RESULTS--
TIME  SH    TS     TA     T8     RT     RH   DQ   LH   GAMMA
 24  0.26  13.3   6.0   1.0 -0.17  82.9 0.06 0.021   8.22
  TE    QE
 0.010 -0.020
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.7  -1.2     0.0    0.046  -0.060   0.87
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.505 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 2.1
```

```
VALID: 17NOV81/12Z TO 18NOV/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  9.9    3.0    0.250 -  7.6 1.7   0.133  -2.5 1.4 1.525   8.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.27  12.9    5.3  -0.2 -0.15  81.9 0.19 0.041    8.57
  TE     QE
 0.009 -0.044
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 3.3  -1.0      0.0     0.036  -0.084   2.42
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.585 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 2.6

VALID:25NOV81/12Z TO 26NOV/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
 11.9  10.0    0.000    8.8 5.0   0.000   -1.5 3.5 1.510   5.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.04  11.9   10.1  -1.4 -0.13 101.2 0.06 0.067    8.82
  TE     QE
 0.009 -0.015
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 0.9  -3.1      2.0     0.236  -0.294   1.53
AIR COLUMN WAS OVER WATER  20  HOURS
DEPTH OF PBL = 1.612 KM
SNOWFALL =    6.3 CM
CLOUD AMOUNT = 9.0

VALID: 27NOV82/12Z TO 28NOV/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  8.6  -8.0    0.188    6.8 1.3   0.094 -10.5 0.9 1.540   9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.46  11.6   -0.0  -2.5 -0.16  83.6 0.18 0.039    9.17
  TE     QE
 0.021 -0.102
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 9.0  -1.7      0.3     0.487  -1.000   3.23
AIR COLUMN WAS OVER WATER  16  HOURS
DEPTH OF PBL = 1.685 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 4.4
```

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VALID: 3DEC81/00Z TO 4DEC/00Z
--INITIAL CONDITIONS--
  TS    TA     DTS    QS  QA   DQS    T8   Q8   Z8    U
 10.9  3.0   0.000   8.0 3.8  0.000  -6.7 2.2 1.555  6.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.15  10.9   5.0  -4.7 -0.13  96.6 0.08 0.050  10.05
  TE    QE
 0.021 -0.046
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.8  -2.5     0.9    0.683  -0.644   1.52
AIR COLUMN WAS OVER WATER  16  HOURS
DEPTH OF PBL = 1.715 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0

VALID: 4DEC81/00Z TO 5DEC/00Z
--INITIAL CONDITIONS--
  TS    TA     DTS    QS  QA   DQS    T8   Q8   Z8    U
  7.7  -7.0   0.188   6.5 1.2  0.093 -10.0 0.9 1.510 10.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.47  10.0  -1.0  -4.0 -0.16  83.5 0.19 0.050   9.25
  TE    QE
 0.022 -0.092
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 6.7  -1.4     0.2    0.481  -0.633   2.55
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.620 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.5

VALID: 5DEC81/00Z TO 6DEC/00Z
--INITIAL CONDITIONS--
  TS    TA     DTS    QS  QA   DQS    T8   Q8   Z8    U
  6.6  -7.0   0.500   6.0 1.1  0.225 -11.5 0.6 1.535 11.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.61  10.6  -2.2  -6.7 -0.04  73.9 0.24 0.000  11.00
  TE    QE
 0.022 -0.070
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 5.1  -0.9     0.0    0.535  -0.448   1.94
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.615 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 5.9
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VALID: 6DEC81/00Z TO 7DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  6.6   3.0    0.333    6.0 1.3   0.150   -6.5 1.3 1.515   8.0
VERTICAL VELOCITY OF AIR PARCEL =  0   CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.21   10.6    4.4   -5.1 -0.14   90.6 0.17 0.133   10.34
  TE     QE
 0.022 -0.076
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 2.2  -1.3      0.4     0.198  -0.459    2.00
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.610 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 9.0

VALID: 7DEC81/00Z TO 8DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  6.4  -6.0    0.333    6.0 1.0   0.150 -11.0 1.6 1.500 12.0
VERTICAL VELOCITY OF AIR PARCEL =  0   CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.51    9.7    0.2   -4.8 -0.17 101.0 0.24 0.248    9.67
  TE     QE
 0.023 -0.076
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 6.2  -3.6      2.6     0.983  -0.768    2.59
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.597 KM
SNOWFALL =    2.4 CM
CLOUD AMOUNT = 9.0

VALID: 8DEC81/00Z TO 9DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS      QS  QA    DQS     T8    Q8    Z8     U
  6.2   2.0    0.267    5.9 1.7   0.120   -4.0 1.3 1.510   7.5
VERTICAL VELOCITY OF AIR PARCEL =  0   CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.21   10.2    3.8   -2.2 -0.15   83.8 0.14 0.048    8.22
  TE     QE
 0.009 -0.040
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 2.8  -1.1      0.1     0.045  -0.118    2.09
AIR COLUMN WAS OVER WATER  15  HOURS
DEPTH OF PBL = 1.520 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 2.4
```

```
VALID: 9DEC81/00Z TO 10DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  6.1    2.0   0.210    5.9 1.6  0.094  -2.5 1.8 1.550  6.6
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.18  10.1   3.7  -0.8 -0.18  89.1 0.12 0.077   7.04
  TE    QE
 0.009 -0.041
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.9  -1.7     0.3    0.077  -0.255   2.28
AIR COLUMN WAS OVER WATER  19  HOURS
DEPTH OF PBL = 1.550 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 3.4

VALID: 10DEC81/00Z TO 11DEC/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  6.0    2.0   0.250    5.8 2.2  0.112  -3.0 2.0 1.550  5.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.15  10.0   2.9  -2.1 -0.15  83.3 0.09 0.031   7.83
  TE    QE
 0.009 -0.027
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.0  -1.2     0.1    0.052  -0.104   1.36
AIR COLUMN WAS OVER WATER  16  HOURS
DEPTH OF PBL = 1.550 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 1.6

VALID: 4DEC81/12Z TO 5DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8     U
  6.9  -1.0    0.210    6.1 1.2  0.100 -11.0 0.6 1.525  7.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS     TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.23  10.9   3.2  -6.8 -0.04  79.3 0.16 0.001  11.59
  TE    QE
 0.021 -0.074
SENS.   RAD.    LAT.   T.ENT.  Q.ENT.  Q.TOT.
 4.7  -1.1     0.1    0.602  -1.335   2.93
AIR COLUMN WAS OVER WATER  19  HOURS
DEPTH OF PBL = 1.715 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 8.2
```

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VALID: 8DEC81/12Z TO 9DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  6.2  -5.0   0.310   5.8 1.8  0.150  -6.5 1.4 1.540 10.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH   GAMMA
 24  0.46  10.2   0.4  -1.1 -0.19  85.4 0.17 0.128   7.37
  TE     QE
 0.009 -0.041
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 6.5  -1.5      0.3     0.059  -0.177   2.35
AIR COLUMN WAS OVER WATER  13  HOURS
DEPTH OF PBL = 1.605 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 2.2

VALID: 14DEC81/12Z TO 15DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  5.4  -4.0   0.500   5.5 0.9  0.250 -12.0 1.0 1.530 15.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH   GAMMA
 24  0.54   9.4   1.3  -6.7 -0.14 100.1 0.31 0.335  10.55
  TE     QE
 0.022 -0.081
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 4.8  -1.4      1.3     0.605  -0.669   2.46
AIR COLUMN WAS OVER WATER  8  HOURS
DEPTH OF PBL = 1.610 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 9.0

VALID: 19DEC81/12Z TO 20DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8   Z8    U
  5.2  -4.0   0.400   5.5 1.0  0.200  -4.5 0.6 1.500 15.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH   GAMMA
 24  0.56   9.2   1.2   0.7 -0.04  68.5 0.26 0.000   5.66
  TE     QE
 0.001 -0.007
SENS.    RAD.    LAT.    T.ENT.  Q.ENT.  Q.TOT.
 6.1  -0.9      0.0     0.029  -0.045   2.82
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.500 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 0.0
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VALID: 20DEC81/12Z TO 21DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  5.1  -2.0    0.250    5.8 2.0  0.125   -2.0 1.3 1.510  7.4
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.26   9.1    1.2    1.2 -0.04  65.5 0.13 0.000    5.20
  TE    QE
 0.001 -0.005
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 4.1  -0.9      0.0     0.029  -0.050   2.05
AIR COLUMN WAS OVER WATER  16  HOURS
DEPTH OF PBL = 1.510 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 23DEC81/12Z TO 24DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  5.0  -4.0    0.250    5.5 1.8  0.125   -7.5 0.6 1.500  9.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.33   9.0    1.0   -2.5 -0.04  76.5 0.14 0.000    7.69
  TE    QE
 0.001 -0.006
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 5.8  -0.9      0.0     0.028  -0.056   2.38
AIR COLUMN WAS OVER WATER  16  HOURS
DEPTH OF PBL = 1.580 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0

VALID: 28DEC81/12Z TO 29DEC/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  4.7  -8.0    0.400    5.2 0.7  0.150 -13.0 0.5 1.480  8.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.46   9.5   -2.5   -7.5 -0.04  77.5 0.18 0.000   11.49
  TE    QE
 0.023 -0.075
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 5.8  -0.9      0.0     0.549  -0.644   2.17
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.600 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 7.4
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VALID: 1JAN82/00Z TO 2JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  4.4  -7.0    0.330    5.2 1.5  0.150  -9.0 0.9 1.480  7.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.36   8.4  -3.2  -5.2 -0.04  67.9 0.13 0.000   9.18
  TE     QE
 0.011 -0.031
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 4.4  -0.9      0.0     0.276  -0.283    1.50
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.570 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 0.0


VALID: 2JAN82/00Z TO 3 JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  8.3    6.0    0.000    6.8 4.5  0.000   0.0 0.9 1.530  2.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.03   8.3    5.8  -0.2 -0.04  32.7 0.02 0.000   5.52
  TE     QE
 0.001 -0.002
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 0.7  -0.9      0.0     0.028  -0.031    0.61
AIR COLUMN WAS OVER WATER  24  HOURS
DEPTH OF PBL = 1.530 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 0.0


VALID: 4JAN82/00Z TO 5JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     T8    Q8    Z8     U
  4.1 -13.0    0.230    5.0 0.5  0.110 -12.0 0.8 1.500  8.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.51   6.4  -8.0  -7.0 -0.04  77.1 0.15 0.000   8.90
  TE     QE
 0.011 -0.033
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 5.7  -0.9      0.0     0.273  -0.262    1.56
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.587 KM
SNOWFALL =    0.0 CM
CLOUD AMOUNT = 1.7
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VALID: 8JAN82/00Z TO 9JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     TS   QS   ZS    U
  3.8  -8.0   0.440   4.9 1.5  0.190  -3.0 1.8 1.440  8.8
VERTICAL VELOCITY OF AIR PARCEL =  .5  CM/S
--RESULTS--
TIME  SH    TS    TA    TS    RT    RH   DQ   LH   GAMMA
 24  0.69   7.8  -8.9  -3.9 -0.25  88.8 0.16 0.139   8.09
  TE    QE
 0.010 -0.027
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 6.1  -1.7     0.5    0.065  -0.109   1.36
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.445 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 3.7


VALID: 9JAN82/00Z TO 10JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     TS   QS   ZS    U
  7.8    0.0   0.000   6.8 3.3  0.000  -2.5 1.4 1.450  5.0
VERTICAL VELOCITY OF AIR PARCEL =  .5  CM/S
--RESULTS--
TIME  SH    TS    TA    TS    RT    RH   DQ   LH   GAMMA
 24  0.20   7.8  -1.1  -3.6 -0.04  69.9 0.06 0.000   7.86
  TE    QE
 0.001 -0.003
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 3.4  -0.9     0.0    0.029  -0.035   1.10
AIR COLUMN WAS OVER WATER  16  HOURS
DEPTH OF PBL = 1.530 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0


VALID: 10JAN82/00Z TO 11JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS     TS   QS   ZS    U
  7.7    1.0   0.000   6.5 2.5  0.000   6.0 2.7 1.460  8.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    TS    RT    RH   DQ   LH   GAMMA
 24  0.19   7.7   2.8   7.8 -0.04  52.0 0.10 0.000  -0.10
  TE    QE
 0.001 -0.004
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 2.7  -0.9     0.0    0.030  -0.036   1.49
AIR COLUMN WAS OVER WATER  12  HOURS
DEPTH OF PBL = 1.460 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 0.0
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VALID: 11JAN82/00Z TO 12JAN/00Z
--INITIAL CONDITIONS--
  TS    TA     DTS    QS  QA   DQS    T8   Q8   Z8    U
  3.7 -15.0   0.440   4.9 0.3  0.190 -22.0 0.3 1.450 13.8
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.82   7.7  -5.2 -12.2 -0.14 100.9 0.28 0.209  13.68
  TE    QE
 0.047 -0.151
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 9.1  -1.5     1.5    0.707  -0.937   2.59
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.540 KM
SNOWFALL =   1.7 CM
CLOUD AMOUNT = 9.0

VALID: 12JAN82/00Z TO 13JAN/00Z
--INITIAL CONDITIONS--
  TS    TA     DTS    QS  QA   DQS    T8   Q8   Z8    U
  3.6 -17.0   0.444   4.8 0.3  0.189 -20.5 0.5 1.500 13.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.86   7.6  -7.3 -10.8 -0.17  99.4 0.26 0.183  12.25
  TE    QE
 0.045 -0.144
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 9.4  -1.7     1.4    0.708  -0.893   2.36
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.590 KM
SNOWFALL =   0.2 CM
CLOUD AMOUNT = 9.0

VALID: 13JAN82/00Z TO 14JAN/00Z
--INITIAL CONDITIONS--
  TS    TA     DTS    QS  QA   DQS    T8   Q8   Z8    U
  3.5 -14.0   0.400   4.8 0.4  0.170 -20.0 0.3 1.480 11.2
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH    TS    TA    T8    RT    RH   DQ   LH   GAMMA
 24  0.68   7.5  -6.1 -12.1 -0.15  92.8 0.23 0.138  13.27
  TE    QE
 0.046 -0.138
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 7.9  -1.5     0.8    0.691  -0.899   2.25
AIR COLUMN WAS OVER WATER  10  HOURS
DEPTH OF PBL = 1.580 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
```

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VALID: 14JAN82/00Z TO 15JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS      T8    Q8    Z8     U
  7.4  -4.0   0.000    6.3 1.2  0.000   -7.5 1.5 1.470  9.8
VERTICAL VELOCITY OF AIR PARCEL =  .75  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.55   7.4  -4.7  -8.2 -0.18  98.2 0.19 0.150  10.62
  TE    QE
 0.023 -0.050
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 4.3  -1.7     1.0    0.618  -0.507   1.47
AIR COLUMN WAS OVER WATER  7  HOURS
DEPTH OF PBL = 1.540 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0


VALID: 19JAN82/00Z TO 20JAN/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS      T8    Q8    Z8     U
  3.3 -16.0   0.444    4.8 0.4  0.167 -15.5 0.5 1.470 14.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.92   7.3  -6.8  -6.3 -0.20  85.1 0.25 0.166   9.22
  TE    QE
 0.023 -0.092
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
 9.8  -1.3     0.3    0.534  -0.545   2.44
AIR COLUMN WAS OVER WATER  9  HOURS
DEPTH OF PBL = 1.555 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.9


VALID: 11JAN82/12Z TO 12JAN/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA    DQS      T8    Q8    Z8     U
  3.6 -14.0   0.222    4.8 0.3  0.089 -26.0 0.2 1.470  9.3
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH   DQ    LH    GAMMA
 24  0.42   7.6  -2.9 -14.9 -0.10 100.2 0.17 0.072  15.32
  TE    QE
 0.044 -0.125
SENS.   RAD.   LAT.   T.ENT.  Q.ENT.  Q.TOT.
10.2  -1.8     1.8    0.904  -1.625   3.21
AIR COLUMN WAS OVER WATER  18  HOURS
DEPTH OF PBL = 1.650 KM
SNOWFALL =   3.6 CM
CLOUD AMOUNT = 9.0
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VALID: 19JAN82/12Z TO 20JAN/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8    Z8     U
  4.3  -4.0   0.140    5.2 1.0  0.050  -9.0 0.7 1.480  8.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.24    7.4    0.5   -4.5 -0.17  91.9 0.10 0.087    8.00
  TE     QE
 0.009 -0.045
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 5.8  -2.0      0.6     0.122  -0.411    2.71
AIR COLUMN WAS OVER WATER  22  HOURS
DEPTH OF PBL = 1.592 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 4.5

VALID: 26JAN82/12Z TO 27JAN/12Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8    Z8     U
  3.1  -8.0   0.308    4.8 0.4  0.115 -20.0 0.4 1.505 10.5
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.39    7.1  -1.5 -13.5 -0.10 101.3 0.20 0.105  13.70
  TE     QE
 0.044 -0.124
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 6.0  -1.5      1.3     0.764  -1.172    2.59
AIR COLUMN WAS OVER WATER  13  HOURS
DEPTH OF PBL = 1.635 KM
SNOWFALL =   2.0 CM
CLOUD AMOUNT = 9.0

VALID: 6FEB82/00Z TO 7FEB/00Z
--INITIAL CONDITIONS--
  TS     TA      DTS     QS  QA   DQS     T8   Q8    Z8     U
  2.9 -10.0   0.222    4.8 0.5  0.083 -16.1 0.4 1.500 11.0
VERTICAL VELOCITY OF AIR PARCEL =  0  CM/S
--RESULTS--
TIME  SH     TS     TA     T8     RT     RH    DQ    LH    GAMMA
 24  0.38    6.9  -1.4  -7.5 -0.15  95.6 0.17 0.104    9.63
  TE     QE
 0.022 -0.096
SENS.   RAD.    LAT.    T.ENT.  Q.ENT.   Q.TOT.
 8.9  -2.1      1.2     0.574  -1.275    3.33
AIR COLUMN WAS OVER WATER  18  HOURS
DEPTH OF PBL = 1.672 KM
SNOWFALL =   0.0 CM
CLOUD AMOUNT = 9.0
```

VALID: 12FEB82/12Z TO 13FEB/12Z
--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z8	U
3.8	3.0	0.200	5.0	2.0	0.070	-6.0	1.5	1.540	4.7

VERTICAL VELOCITY OF AIR PARCEL = 0 CM/S
--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
24	0.08	6.8	2.8	-6.2	-0.11	82.9	0.07	0.022	8.43

TE	QE
0.009	-0.020

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
0.8	-1.1	0.0	0.044	-0.064	0.96

AIR COLUMN WAS OVER WATER 15 HOURS
DEPTH OF PBL = 1.555 KM
SNOWFALL = 0.0 CM
CLOUD AMOUNT = 2.6

APPENDIX H

EXAMPLE OF A SNOW FORECAST FOR SEOUL, KOREA

VALID: 19DEC81/00Z TO 19DEC/12Z (SEOUL, KOREA)

--INITIAL CONDITIONS--

TS	TA	DTS	QS	QA	DQS	T8	Q8	Z0	U
5.5	-5.0	0.108	5.7	0.6	0.042	-12.5	0.9	1.450	10.9

VERTICAL VELOCITY OF AIR PARCEL = 2 CM/S

--RESULTS--

TIME	SH	TS	TA	T8	RT	RH	DQ	LH	GAMMA
1	0.94	5.6	-4.4	-11.9	-0.04	52.0	0.45	0.000	12.09
2	0.89	5.7	-3.9	-11.4	-0.04	74.0	0.42	0.000	11.80
3	0.85	5.8	-3.2	-10.7	-0.15	91.2	0.38	0.325	11.38
4	0.79	5.9	-2.4	-9.9	-0.15	100.1	0.36	0.426	10.93
5	0.72	6.0	-1.8	-9.3	-0.15	105.0	0.34	0.348	10.59
6	0.68	6.1	-1.2	-8.7	-0.15	107.4	0.32	0.400	10.25
7	0.63	6.3	-0.7	-8.2	-0.15	105.6	0.30	0.354	9.97
8	0.59	6.4	-0.3	-7.8	-0.15	105.0	0.28	0.320	9.75
9	0.56	6.5	0.1	-7.4	-0.15	104.5	0.27	0.289	9.56
10	0.54	6.6	0.4	-7.1	-0.15	104.0	0.26	0.262	9.42
11	0.52	6.7	0.7	-6.8	-0.15	103.7	0.25	0.238	9.30
12	0.50	6.8	0.9	-6.5	-0.15	103.4	0.24	0.217	9.21

TE	QE
0.023	-0.099

SENS.	RAD.	LAT.	T.ENT.	Q.ENT.	Q.TOT.
8.2	-1.6	3.2	0.334	-1.001	3.37

AIR COLUMN WAS OVER WATER 12 HOURS

DEPTH OF PBL = 1.557 KM

PRECIP WATER = 0.9 GRAMS

SNOWFALL = 9.3 CM

CLOUD AMOUNT = 9.0